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TREATMENT OF THEINDUSTRIAL WASTEWATER OF KASIH FACTORY BY COAGULATION-FLOCCULATION AND SEDIMENTATION

By
Alaa' Bassam Al Falaileh

Supervisor
Dr. Bashar M. Al Smadi

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COMMITTEE DECISION

This Thesis (Treatment of the Industrial Wastewater of Kasih Factory by coagulation-flocculation and sedimentation) was successfully defended and approved on April 14th, 2011

Examination Committee	Signature
Dr. Bashar M. Al Smadi (Supervisor) Assist. Prof. of Environmental Engineering	
Dr. Ahmad Jamrah Prof. of Environmental Engineering	
Dr. Khaldoun Shatanawi Assist. Prof. of Hydraulics and Hydrology	
Dr. Mohanned Al-Sheriadeh Assoc. Prof. of Water Resources & Environmental Engineering (Jordan University of Science and Technology)	

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LIST OF ABBREVIATIONS

Symbol	**Notation**
ABR	Anaerobic Baffled Reactor
AF	Anaerobic Filtration
BOD	Biochemical Oxygen Demand
BOD_T	Total BOD
COD	Chemical Oxygen Demand
HRT	Hydraulic Retention Time
MBRs	Membrane Reactors
MF	Microfiltration
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
OLRs	Organic Loading Rates
OpCD	Optimal Coagulant dose
OpH	Optimal pH
PAC	Powder Activated Carbon
RPM.	Revolution per minute
sBOD	Soluble BOD
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UF	Ultrafiltration
VSS	Volatile Suspended Solids

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ABSTRACT

Wastewater from food industries represents one of the environmental problems. This study deals with the bean soaking and blanching wastewater and dried yoghurt soaking (desalting) from Kasih Food Production Company. It faces the problem of discharging its wastewater without treatment. This work is objected to study the treatment of the industrial wastewater of Kasih Factory to meet the Jordanian Standards for the discharge of reclaimed wastewater for field crop and forest trees by using coagulation-flocculation and sedimentation. It was founded that the OpH is 7.0 for bean soaking to remove 56.58% BOD_5, 71.62% COD, %37.05 TSS and 38.36% TDS while 68.8% BOD_5, 80.7% COD, %38.76 TSS and %12.0 TDS for bean blanching, but the OpH for dried yoghurt soaking (desalting) is 4 to remove 76.9% BOD_5, 60.6% COD, 63.8% TSS and 45.1% TDS.

Ferric chloride is used as coagulant for bean soaking and blanching effluents. Results indicated that an optimal coagulant dose (OpCD) of ferric chloride for bean soaking is 200 mg/l to remove 91.7% BOD_5, 89.9% COD, 57.94% TSS and 66.05% TDS, while it is 500 mg $FeCl_3.6H_2O$/l for treating bean blanching effluent to remove 89.9% BOD_5, 90.84% COD, 75.15% TSS and 57.62% TDS. From using higher dose above the optimal coagulant dose will not increase the BOD_5, COD, TSS and TDS removals. Chitosan polymer is used as a coagulant for dried yoghurt soaking wastewater treatment. The OpCD found is 30 mg/l of chitosan. It removed 84 % BOD, 74.3 % COD, 87.3 % TSS and 47 % TDS.

CHAPTER ONE

Introduction

1.1 Background

Whenever and wherever food, in any form, is handled, processed, packed and stored, there will always be an unavoidable generation of wastewater. Wastewater is the most serious environmental problem in the manufacturing and processing of foods (Liu, 2007).

The food industry is now facing increasing pressure to ensure that their company's activities are environmentally sensitive. Therefore, the generated wastewaters need to be treated and the importance of wastewater treatment in the food industry is growing nowadays, because of the rising cost of water and because of the need to comply with environmental pollution regulations (Ildikó Galambos et al., 2004).

Knowledge of characteristics of food processing wastewater is essential to the development of economical and technically viable wastewater management systems that are in compliance with current environmental policies and regulations.

Each food processing plant produces wastewater of different characteristics. No two plants, even with similar processing capacity of food products, will generate wastewater of the same quantity and quality because there are too many variables (technical or otherwise) in the process that ultimately define characteristics of wastewater. Furthermore, even different periods of food processing in the same plant may produce different wastewater streams with different characteristics (Liu, 2007). This research focuses on studying treatment of food processing effluent from the Kasih Food Production Company in Amman, Jordan.

This company is selected because it is one of the leading Jordanian manufacturers of canned and boxed Mediterranean food; they produce bean (large+ small bean), chick peas,

green peas, tomato paste and dried yoghurt. This study will focus on the bean process wastewater and dried yoghurt wastewater.

For Bean production Processes:

The wastewater effluents from this production process are soaking and blanching wastewater. The production process is explained in the following:

1. Manual sorting: all impurities (stones, stems and rotten seeds) are sorted manually.
2. Soaking in water for 15-20 hours. At the end of the soaking stage wastewater is discharged to the sewer (Effluent 1).
3. The soaked is pumped to the vibration steps.
4. Blanching at 90°C (Effluent 2): Blanching is done continuously for legumes in a local made cylindrical vessel which has a rotating cylindrical sieve where legumes are being blanched by hot water and moved through the sieve until reaching the conveyer belt.
5. Manual sorting through conveyor belt to make sure that there is no stones or rotten seeds, and then they move by vibration steps to the cans.
6. Filling the cans with products and with saline solution.
7. Sealing the cans.
8. Entering the cans to the Autoclean to sterilize them by hot water.
9. Labeling the cans.
10. Passing the cans through X-rays to reject the non conforming cans.
11. Packaging the cans and moving to the store.

For Dried yoghurt production processes:

The wastewater effluent from this production process is soaking (desalting) wastewater. The production process is explained in the following:

1. Soaking the yoghurt stones (Jameed) in water to become soft and smooth which produce (Effluent 3).
2. Moving them by pipe to the first mixer tank.
3. Moving them to the second mixer tank and diluting them by water.
4. Filtering them
5. The liquid is sterilized and packed in sterilized aluminum bags to keep it stable at room temperature.

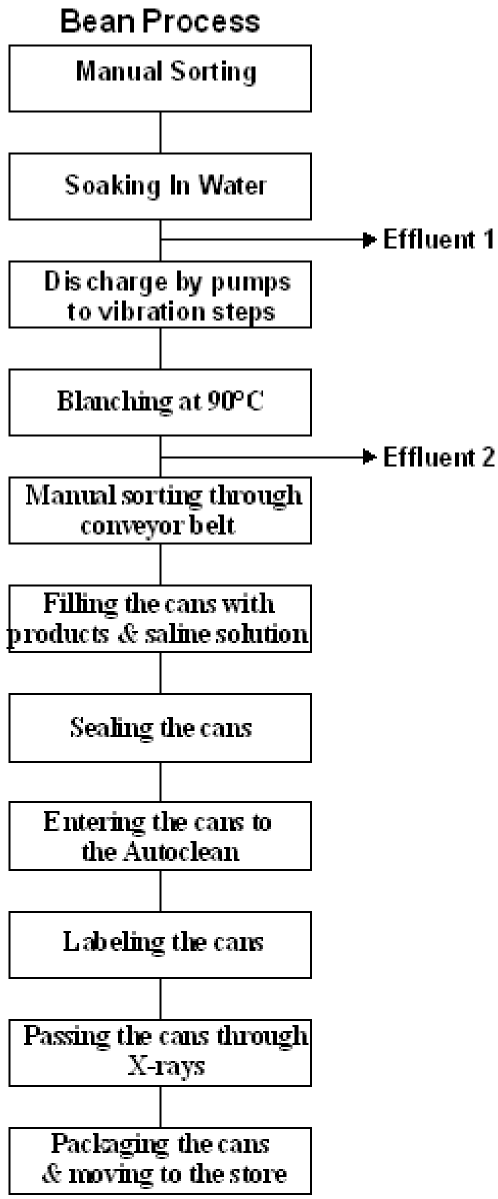

Fig. (1.1): Bean Process Flowchart

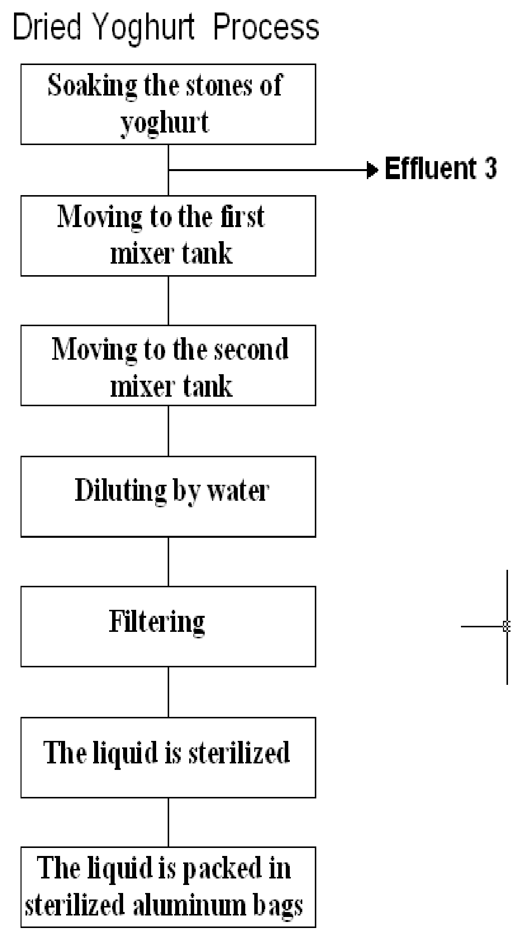

Fig. (1.2): Dried Yoghurt Process Flowchart

Wastewater sources and quantities generated at Kasih factory show in table 1.1.

Table 1.1: Wastewater Sources and quantities generated at Kasih Factory.

Name of product	**Wastewater Sources**	**Wastewater Amount (m^3/day)**
Bean (Large+ small Bean)	Soaking	10
	Blanching	5
Dried yoghurt	Soaking (desalting)	32

1.2 The importance of the study

Industrial Wastewater of Kasih Factory is a potentially source of pollutants that discharges directly to the public sewer system without treatment. Because these generated wastewaters have high solids content and high organic matter concentrations, it has a negative impact on the receiving wastewater treatment plant. Therefore, this effluent has to be treated before it is discharged to the sewer network.

1.3 Objectives of the study

The objective of this research is to study the treatment of the industrial wastewater of Kasih Factory to meet the Jordanian Standards (JS 202:2007) for discharge of industrial reclaimed wastewater for crop field and forest tree irrigation as show in Table 1.2.

Table 1.2: Maximum allowable concentration for crop field and forest tree irrigation (mg/l).

Maximum allowable concentration for crop field and forest tree irrigation (mg/l)	
BOD	300
COD	500
TSS	300
TDS	2000
pH	6-9

These parameters are selected to study according to the last Factory's analysis in September, 2008 for wastewaters released which indicate that there is a problem in these parameters as show in Table 1.3.

Table 1.3: The last Factory's analysis for wastewaters released from production processes.

Wastewater source	Biochemical Oxygen Demand (BOD) mg/l	Chemical Oxygen Demand (COD) mg/l	Total Suspended Solids (TSS) mg/l	Total Dissolved Solids (TDS) mg/l
Soaking	3553	15923	648	8000
Blanching	3689	50396	2400	19970
Dried yoghurt soaking	3856	40427	5788	31160

Coagulation-flocculation is suggested for the treatment of this effluent. This study will investigate the optimum chemical dose for reducing the biochemical oxygen demands (BOD_5), the chemical oxygen demand (COD), the total suspended solids (TSS) and the total dissolved solids (TDS) in the effluent.

CHAPTER TWO

Literature Review

2.1. Introduction

Water consumption is a major concern of the food industry. Apart from its frequent use as an ingredient, most of it ends up in the wastewater stream (Klemeš et al., 2008).

Different sources contribute to the generation of wastewater in food processing industries, including, dairy products, vegetable processing and bean products. Wastewaters released from these industries are turbid, with high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and suspended solids (SS) (Lawrence *et al.*, 2006).

Table 2.1 lists the industrial effluent parameters and their upper limits for wastewater reuse according to Jordanian standards for field crop and forest trees irrigation.

Table (2.1): Industrial effluent parameters, significance and maximum concentration of treated wastewater.

Parameter [a]	**Significance** [a]	**Maximum concentration of treated wastewater** [b]
Total suspended solids (TSS)	TSS can lead to sludge deposits and anaerobic conditions. Excessive amounts cause clogging of irrigation systems. Measures of particles in wastewater can be related to microbial contamination, turbidity can interfere with disinfection effectiveness	300 mg/l
Biochemical oxygen demand and chemical oxygen demand (BOD, COD)	Their biological decomposition can lead to depletion of oxygen. For irrigation only excessive amounts cause problems. Low to moderate concentrations are beneficial.	BOD = 300 mg/l COD = 500 mg/l
pH	Affects metal solubility and alkalinity and structure of soil, and plant growth.	6-9

a: Kretschmer et al., 2000
b: Industrial reclaimed wastewater for field crops, industrial crops and forest trees irrigation- Jordan institution for Standards and Metrology.

Other characteristics of food processing wastewater are (a) large seasonal variation; (b) large hourly variation and concentration in daytime, (c) factories are often of small scale, and (d) colored effluent (Lawrence *et al.*, 2006).

2.2. Coagulation

Coagulation has been defined as the addition of a chemical, such as metal salts, to a colloidal dispersion that results in particle destabilization by the reduction of surface charges and the formation of complex hydrous oxides that form flocculent suspensions (Eckenfelder, 1980). Colloids present in wastewater can be either hydrophobic or hydrophilic. The hydrophobic colloids (clay, etc.) possess no affinity for the liquid medium and lack stability in the presence of electrolytes. Hydrophilic colloids, such as proteins, exhibit marked affinity for water. The absorbed water retards flocculation and frequently requires special treatment to achieve effective coagulation. Colloids have diameters usually less than 10 µm and remain suspended in water because their sedimentation by gravity is less than 10^{-2} cm/sec, they also have zeta potential of 15 to -20 mV, the time periods over which colloidal systems are stable can range from few seconds to several years (Faust and Aly, 1998; Eckenfelder, 1980).

The zeta potential is a measure of stability of a particle and indicates the potential that would be required to penetrate the layer of ions surrounding the particle for destabilization as shown in Fig. (2.1).

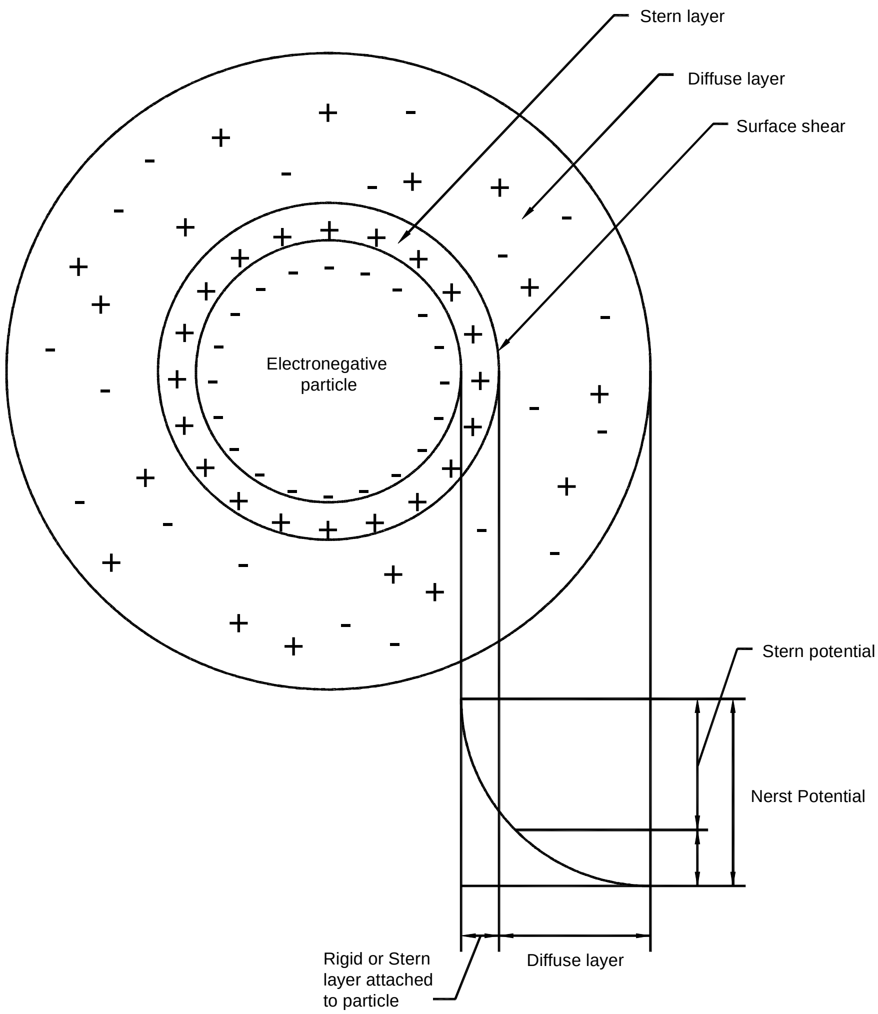

Fig (2.1): Guoy-Stern colloidal model (McGhee, 1991).

Most colloidal particles are negatively charged as shown in Fig 2.1. The stationary charged layer on the surface is surrounded by a bound layer of water in which ions of opposite charge drawn from the bulk solution produce a rapid drop in potential. This drop within the bound water layer is called the Stern potential. A more gradual drop, called the zeta potential, occurs between the shear surface of the bound water layer and the point of electroneutrality in the solution. The surface charge on colloidal particles is the major contributor to their long-term stability (McGhee, 1991).

As zeta potential gets higher, the particle gets more stabilized. The purpose of coagulation is to reduce the zeta potential by adding specific ions and then induce motion for the destabilized particles to agglomerate. Four mechanisms are proposed to accomplish the process: (Peavy, et al., 1987; Berdal, 2007).

1. Ionic layer compression: A high ionic concentrations compress the layers composed predominantly of counter ions toward the surface of the collide. If this layer is sufficiently compressed, the van der waals forces will be predominating across the entire area of influence, so that the net force will be attractive and no energy barriers will exist.
2. Adsorption and charge neutralization: Charge neutralization occurs generally at low metal concentrations. Coagulation with aluminum or iron salts follows three steps:
   a. Addition of a dose of coagulant that exceeds the operational solubility limit of aluminum (or iron) hydroxide,
   b. Aluminum or iron hydroxide species are then deposited onto colloidal surfaces,
   c. Charge neutralization or even charge reversal of the colloidal particle.

   Metal hydroxides are generally positive and colloidal impurities negative, charge neutralization is thought to dominate in water containing Natural Organic Matter (NOM) or algae. Charge neutralization is rapid and can be achieved at quite low coagulant dosages, but the dosage should be proportional to the contaminant concentration. Small flocs are produced, giving poor removal efficiency.
3. Sweep coagulation: When concentrations exceeding saturation doses are used, aluminum and iron from insoluble precipitates and impurities become captured in these precipitates. This mechanism predominates where pH values are between 6 and 8, close to the coagulant minimum solubility to give a quick aggregation; the dosage is independent of the type of

particles contained in the water but dependent on the pH. Sweep flocculation dominates at higher dosages and is slower. Big flocs are produced but they are weak.

4. Interparticle bridging: large molecules may be formed when aluminum or ferric salts dissipates in water. Synthetic polymers also may be used instead of or in addition to metallic salts.

The chemicals commonly used in coagulation include aluminum sulphate, ferric chloride, ferric sulfate, ferrous sulfate and lime, and chlorinated copperas. The choice is dedicated by relative cost and effectiveness in particular areas. (McGhee, 1991).

Aluminum sulphate finds almost exclusive application in drinking water treatment, whereas the iron compounds are used predominantly in treating domestic and industrial wastewaters.(Faust and Aly, 1998). Destabilization can also be accomplished by the addition of cationic polymer, which can bring the system to the isoelectric point without a change in the pH. Although cationic polymer are 10 to 15 times as effective as alum as a coagulant, they are considerably more expensive (Eckenfelder, 1980). The effectiveness of the coagulation process is influenced by the coagulation agent, the coagulant dosage, the solution pH and ionic strength, as well as the concentration and nuture of the organic compounds (Stephenson and Duff, 1995).

2.2.1. Coagulation with iron salts:

Iron salts are produced from iron-based waste materials using sulphuric or hydrochloric acid. When the salts are dissolved in water, the metal (M) ion hydrates and is hydrolyzed to form monomeric and polymeric species: MOH^{2+} , $M(OH)_2^{+}$, $M_2(OH)_2^{4+}$, $M(OH)_4^{5+}$, $M(OH)_3^{\circ}$ (s) and $M(OH)^{-}_4$ (Stephenson and Duff, 1995).

Under very acidic conditions, Fe^{3+} remains in solution but as the pH is increased or as the coagulant concentration is raised, hydrolysis occurs to form the metal hydroxide $M(OH)_3(s)$, that is ferric hydroxide, $Fe(OH)_3(s)$. In general, the hydrolysis reaction of the trivalent metals is as follows:

$$xM^{3+} + yH_2O = M_x(OH)_y^{(3x-y)+} + yH^+ . \qquad 2.1$$

Iron has a strong tendency to form insoluble complexes with a number of ligands, especially with polar molecules and with oxygen containing functional groups such as hydroxyl or carboxyl groups. These groups provide a local negative charge which reacts with the iron cations (Stephenson and Duff, 1995). Compared with alum ($A1_2 (SO4)_3$), ferric chloride coagulates effectively over a broader pH range, forms a stronger, heavier floe, is less sensitive than alum to problems with filtrate quality upon instances of overdosing. However, liquid ferric chloride is an acidic, corrosive, dark brown solution which causes staining and necessitates special materials of construction.

2.2.2 Coagulant with chitosan

Chitosan, a natural linear biopolyaminosaccharide is obtained by alkaline deacetylation of chitin, which is the principal component of protective cuticles of crustaceans such as crabs, shrimps, prawns, lobsters and cell walls of some fungi (Qin *et al*., 2006).

Chitosan is a weak base and is insoluble in water and organic solvent. However, it is soluble in dilute aqueous acidic solution (pH < 6.5), which can convert glucosamine units into soluble form $R–NH_3^+$. Chitosan is inexpensive, biodegradable, and nontoxic for mammals. This makes it suitable for use as an additive in the food industry (Qin *et al*., 2006).

The main evidence of its low toxicity is that it is present in food that humans consume on a daily basis such as mushrooms and seafood (Li *et al*., 2005). The major functional groups of chitosan are the amino groups that protonate at solution pH ranging from acidic to slightly basic as shown in Figure 2.2

These amino groups are responsible for the positive charges that chitosan carries at natural water pH. Chitosan, with a high content of free amino groups are the most effective in coagulation.

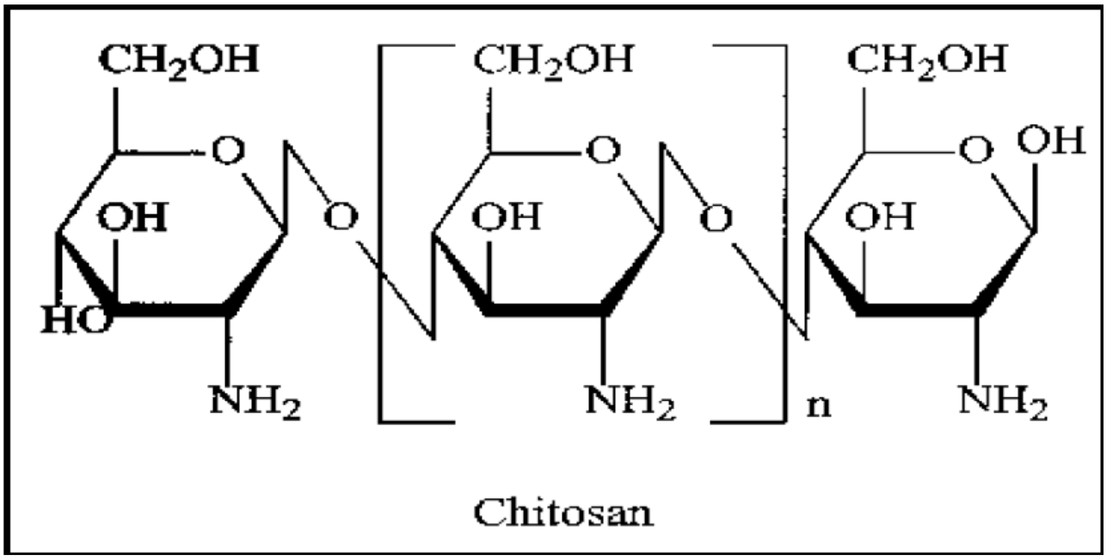

Figure (2.2): Chemical structure of completely deacetylated chitosan

The physical properties of chitosan are varied. Chitosan is a linear polymer with a wide range of molecular weights. Its molecular weight varies with the type of biological material used to manufacture chitosan; the solubility of chitosan varies widely. Usually, acid must be added in order to enable solubilization of chitosan in water (Li *et al*., 2005).

Chitosan, with its positive charge, can be used for coagulation and recovery of proteinaceous materials present in such food processing operations. Under alkaline conditions, chitosan exhibits strong cation exchange behaviour to remove metal ions from

industrial wastewater while under acidic conditions, chitosan causes anion exchange sites to be made available to bind the anion (Gamage *et al*., 2007).

In 1975–1978, extensive studies by Bough and coworkers demonstrated the effectiveness of chitosan for coagulation and recovery of SS in processing wastes from a variety of food processing industries including poultry, eggs, cheese, meat, fruit cakes, seafood and vegetables. These studies indicated that chitosan can reduce the suspended solids (SS) of such processing waste by as much as 65% to 99%. Good results were also obtained for the reduction of chemical oxygen demand (COD). The effectiveness of chitosan as coagulant has also been reported by Johnson and Gallanger (1984), Senstad and Almas (1986), Moore et al. (1987), No et al. (1994), and Sievers et al. (1994). These authors clearly demonstrated that chitosan has an intrinsic capacity to be used as a coagulant to reduce SS and COD. Also they reported that positively charged cationic macromolecules can destabilize the negative colloidal suspension by charge neutralization as well as by bridge formation. In addition, another important advantage must be cited: after being used the sludge may be disposed of with a lower environmental impact than common metal based systems (Renault *et al.*, 2009). Guibal et al. (2005) showed that chitosan can be used as a primary coagulant or as a flocculant after coagulation: it has characteristics of both coagulants and flocculants. Chitosan coagulants also produced larger flocs of better quality and faster settling velocity.

Guibal's group published a series of papers on the ability of chitosan to act as an effective coagulant to treat not only particulate suspensions but also dissolved substances (Renault *et al.*, 2009).

2.3. Treatment of bean wastewater:

There are few studies reported on the examination of coagulation/flocculation for the treatment of bean wastewater, aiming at performance optimization, i.e. selection of the most appropriate coagulant and assessment of pH effect.

2.3.1 Bean wastewater treatment by coagulation - flocculation

Schneider, et al. (1995) examined the volume of soybean proteins settled in the Imhoff cone as a function of pH. They found that maximum settling volume 40-50 ml/l at pH of 4.5. The applied coagulants were alum and ferric chloride. Ferric chloride ($FeCl_3$) showed better results, by coagulant dose of 200-300 mg/l, 28% COD removal in settling stage and 83% suspended solids removal with pH of 4.5. Also Badawy et al. (2006) found that a ferric salt was economically preferable in the treatment. The results showed that the 400 mg/L of $FeCl_3$ removed 63% of COD.

The ratio of BOD/COD in wastewater is normally used to express the biodegradability of the wastewater. When the ratio of BOD/COD is greater than 0.3, the wastewater has a better biodegradability. Whereas the BOD/COD less than 0.3 indicates that the wastewater generated from these activities inhibits the metabolic activity of bacterial seed due to their toxicity or refractory properties and it is difficult to be biodegraded. However, in the case of wastewater from food industry BOD/COD value is more than 0.3 (Badawy et al., 2006).

Syntheses of recent works, presented in Table (2.2), clearly reveal that iron salts are efficient for COD removals (up to 50%).

Table (2.2): Treatment effectiveness of bean wastewater with the use of coagulation

COD_{ini} (mg/l)	BOD_5/COD	pH_{ini}	TSS (mg/l)	Coagulant Type	Coagulant Concentration (mg/l)	COD removal %	References
3323	0.42	8	802	$FeCl_3$	200	58	Badawy et al. (2006)
					300	60	
					400	63	
					500	77	
				$FeCl_3$+cationic polymer	400+2	89	
					400+3	90	
					400+4	95	
				$FeCl_3$ +anionic polymer	400+2	92	
					400+3	95	
					400+4	96	
				$FeCl_3$+PAC	400+100	85	
					400+200	87	
					400+400	90	
					400+600	92	
700-27000		4.5		$FeCl_3$	200-300	28	Schnelder et al. (1995)

2.3.2. Treatment by Membrane Reactors (MBRs)

The 1980s and 1990s have witnessed a rapid growth of research in membrane separation processes (Chai *et al.*, 1999). It can be defined as systems integrating biological degradation of waste products with membrane filtration. They have proven quite effective in removing organic and inorganic contaminants as well as biological entities from wastewater (Cicek, 2003).

MBRs include good control of biological activity, high quality effluent free of bacteria and pathogens, smaller plant size, and higher organic loading rates.

Chai *et al.* (1999) studied the wastewater treatment of bean curd by using the membrane separation method. The wastewater had chemical oxygen demand (COD) of about 10,000 mg/l. They tested the microfiltration (MF) and ultrafiltration (UF) but found inadequate for

COD removal to meet the government foul sewer discharge permit, 3000 mg/l. It shows that there is about 13% removal of COD for the 0.65 mm pore size membrane. When the membrane pore size is reduced to 0.22 mm, the COD removal is only 15.6%. Nanofiltration was found to be a feasible technology for treating this kind of wastewater. The permeate flux and COD were investigated in relation to the transmembrane pressure drop, temperature, and feed solution COD concentration. It has advantages over the reverse osmosis in terms of lower operating pressure and higher permeates flux. The permeate flux was found to increase significantly with transmembrane pressure drop and to decrease with feed concentration. The permeate COD for all the conditions tested meets the discharge permit. The permeate COD decreases with the increase of transmembrane pressure drop and increases with the operation temperature, which is consistent with the theory.

2.3.3. Bean wastewater treatment by Anaerobic Baffled Reactor

Most of the degradation studies on soybean processing wastewater have focused on aerobic and membrane technology; however oxidation processing provides high cost and sludge yield, and membrane pollution is a serious problem which restricts the industrial application of membrane treatment technology. Anaerobic process is an appropriate method for treatment and energy recovery from high strength wastewaters (Zhu *et al*., 2008). The anaerobic baffled reactor (ABR) has many advantages due to no special gas or sludge separation, lower sludge generation, long biomass retention times, low hydraulic retention time and high stability to organic. The ABR was suggested by several researchers as a promising system for industrial wastewater treatment. Zhu *et al*. (2008) used ABR which contained four equal rectangular compartments. Each compartment was further divided into two parts by slanted edge (45^{o}) baffles. The ratio of mixed liquor volatile suspend solid

(MLVSS) to mixed liquor suspend solid (MLSS) was 0.71 in the inoculated sludge. After inoculation, the sludge concentrations of each compartment were 30.9 g MLVSS/L.

The adaptation period is very important since the bacteria population used as seed is going to be exposed to the anaerobic environment of ABR system. After the acclimatization of the anaerobic activated sludge in 24 days, the ABR was subjected to a steady-state operation and the removal of total COD from the wastewater was remarkable (above 92%); At the second stage, the COD removal increased continually when the volume loading rate enhancing, basically about 94%. But at the third stage, when an influent 8000 mg COD/L was applied to the ABR, acidification phenomenon happened during the initial period (65–67 days) because of increasing volume loading rate that resulted in the declination of COD removal to 80%. Four days later, the COD removal was improved to 94% without adopting any measurement (influent COD concentration 8000 mg/L). The COD removal in the last stage was similar to the third stage, when increased volume loading rate further, the total COD removal efficiencies in the ABR system remained as 97% and the effluent COD concentration was under 300 mg/L.

All of these methods are efficient for removing COD, but they are different from each other for some advantages. Anaerobic baffled reactor method is moderate capital costs, moderate operating costs depending on emptying; can be low cost depending on number of users. While membrane reactor is expensive capital and repair costs. Also membrane reactor is brittleness (easy to crack). Chemical coagulant is preferred because it is the fastest methods and do not need expert design and construction like other methods.

2.4. Treatment of Dairy wastewater:

In dairy industries, water has been a key processing medium. Water is used throughout all steps of the dairy industry including cleaning, sanitization, heating, cooling and floor washing. Dairy wastewater is characterized by the high BOD and COD content, high levels of dissolved or suspended solids including fats, oils and grease, nutrients such as ammonia, minerals and phosphates. Therefore they require proper attention before disposal (Sarkar *et al*., 2005).

Since dairy waste streams contain high concentrations of organic matter, these effluents may cause serious problems, in terms of organic load on the local municipal sewage treatment systems (Demirel *et al.*, 2005).

2.4.1. Dairy wastewater treatment by coagulation - flocculation

In recent times, researchers have shifted their interests in possibilities of reuse or recycling of industrial wastewaters — dairy industries are no exceptions. Dairy wastewater generally does not contain conventional toxic chemicals.

Sarkar et al. (2005) studied the effect of dosages of coagulants and pH. They showed that ferric chloride had better results than alum in the removal of COD and suspended solid. The formation of floc followed by settling was appreciable at pH 6.5 and 8.0. No coagulation was observed at pH 4.0 for ferric chloride. Because they used higher dosages of ferric chloride between 100-1000 mg/l, the color of water became orange, so these results prompted them to search for other coagulants. Secondly they used chitosan dosages between 10–100 mg/L at pH 6.5 and 4. A maximum of 22% reduction in TDS and 20% decrease in COD was observed at pH 6.5. At pH 4.0 these reductions were 48% in TDS and 57% in COD at 10–50 mg/L chitosan dosage. For the settling time parameter, it was varied

between 30-150 min at a particular coagulant dosage. After 60 min settling time no further reduction in TDS and COD was observed with time. Approximately 44% TDS and 40% COD reduction after 60 min settling time when treated with 10 mg/L chitosan at pH 4. Whereas Hwa Chi et al. (2006) studied the effect of time on coagulation, pH and coagulant dosage effect. They found that the optimal result was reached under the condition of pH 7 with the coagulant dosage of 25 mg/l chitosan and with 30 min slow mixing and 30 min settling time. The COD removal was 70% under pH 7 and 40% under 25 mg/l chitosan dosage.

Table (2.3) shows that chitosan was found to be a better coagulant compared to inorganic and organic coagulants and Performance of chitosan is pH dependent.

Table (2.3): Treatment effectiveness of dairy wastewater with the use of coagulation – flocculation process by Sarkar et al. (2005).

COD_{ini} (mg/l)	$BOD_{5\ ini}$ (mg/l)	pH_{ini}	TDS_{ini}	Coagulant Type	Coagulant Concentration (mg/l)	COD_{out}	TDS_{out}
1500–3000	350–600	4.0	800–1200	$FeCl_3$	100		1400
					300		1550
					500		1600
					1000		1900
		6.5			100		1500
					300		1300
					500		1200
					1000		1600
		8.0			100		1400
					300		1000
					500		800
					1000		1600
		4.0		Alum	100		1700
					300		1600
					500		1700
					1000		1400
		6.5			100		800
					300		600
					500		600
					1000		1400
		8.0			100		800
					300		1000
					500		800
					1000		1300
		4.0		Chitosan	100	490	490
					300	600	600
					500	800	650
					1000	900	1000
		6.5			100	700	500
					300	800	600
					500	1100	700
					1000	1300	1000
		8.0			100	1500	1700
					300	800	1600
					500	900	1700
					1000	600	1600

2.4.2. Anaerobic treatment for dairy wastewater

In the last two decades, anaerobic processes proved to be highly suitable for the treatment of dairy wastewaters. The results achieved in several high-rate anaerobic reactors treating different dairy wastewaters at organic loading rates (OLR) from 4 to 24 kg COD/ m^3 d.

Anaerobic treatment processes are favorable methods for treating dairy waste effluents, in comparison to aerobic processes, due to their well-known benefits for treating industrial wastewaters, particularly from agricultural industries with a high organic content. Anaerobic treatment applications for dairy industry wastewaters have been evaluated in a number of previous studies (Demirel *et al.*, 2005).

In treatment studies of dairy wastewaters, anaerobic filters have recently been used. If the particular dairy effluents contain low concentrations of suspended solids, then anaerobic filter reactors are generally suitable for biological treatment. A laboratory-scale plastic medium anaerobic filter reactor provided average COD removal rates between 78 and 92%, at a hydraulic retention time (HRT) of 4 days.

Omil et al. (2003) described the pH, COD, TSS and VSS were determined by Standard Methods Full-scale anaerobic treatment during more than 2 years confirmed the results obtained in the laboratory, being possible to operate at moderate OLR (around 5– 6 kg COD/m^3 d), maintaining COD removal efficiencies higher than 90%.

The 12m^3 anaerobic filter reactor (AF) has been in operation for 634 days. The variations of the main parameters used to monitor and control the behavior of the anaerobic process, such as the OLR corresponding to the influent and effluent, total and soluble COD

The whole operational period can be divided in five periods according to the objectives.

2.4.3. Dairy wastewater treatment by Upflow Anaerobic Sludge Blanket Reactor

Upflow anaerobic sludge blanket (UASB) reactors have been successfully employed for dairy wastewater treatment in full-scale applications for almost two decades, since they can treat large volumes of wastewaters in a relatively short period of time (Demirel *et al.*, 2005). Because of the high organic content of dairy wastewater, anaerobic digestion is essentially the only viable treatment method. An Upflow Anaerobic Sludge Blanket (UASB) reactor is a high rate treatment system, especially feasible for treating soluble (containing low solids) wastewaters. A well-performing UASB reactor is characterized by highly flocculated, well-settling, compact methanogenic sludge granules, resulting in very high biomass content (Gavala *et al.*, 1999).

Anaerobic treatability studies of dairy effluents from large integrated industry processing milk were carried out using a laboratory-scale hybrid UASB reactor. At an OLR of 8.5 g COD/ (l day) and an HRT of 5 h, 87% COD removal was achieved at 30º C (Ozturk *et al.*, 1993).

Recently, the feasibility of using UASB reactors for dairy wastewater treatment was explored by operating two types of UASB reactors. The reactors were operated at an HRT range between 3 and 12 hr, and on loadings ranging from 2.4 to 13.5 kg COD/(m^3 day). At 3 h, maximum COD reduction ranged between 95.6 and 96.3%, while at 12 HRT reductions were around 92–90%, for both reactors (Demirel *et al.*, 2005).

Gavala *et al*. (1999) constructed a UASB reactor of 10 liter useful volume and inoculated it with anaerobic mixed liquor from dairy wastewater and glucose fed digesters. They studied the digester efficiency of treating dairy wastewater at various organic loading rates and its performance was assessed by monitoring pH, dissolved chemical oxygen demand (COD), biogas production and composition. Operation at an organic loading rate of 6.2 g COD/l d

was found to be safe and could be increased to a maximum of 7.5 g COD/l d. The maximum digester COD removal efficiency of 98% was reached at an HRT of 6 d with an influent COD concentration of 37 g/l (OLR=6.2 g COD/l d). When increasing the influent COD concentration to 42 g/l (OLR=7.5 g COD/l d), the COD removal efficiency was reduced to 85-90% with a mean COD effluent concentration of 5 g/l. Consequently, the total experiment may be divided into three periods: period I, with almost complete COD removal; period II, with constant influent COD concentration but with a progressive increase in HRT from 6 d to approximately 20 d in order to maintain satisfactory COD removal (80-90%); and period III during which the influent COD concentration was increased to the undiluted value. In this period, the HRT had to increase above 30 d in order to sustain reasonable reactor performance.

For Upflow anaerobic sludge blanket reactor and anaerobic treatment, experts are required for the design, construction, operation and maintenance. Also require seeding (start-up can be long due to the low growth yield of anaerobic bacteria) and they have high sensitivity of methanogenic bacteria to a large number of chemical compounds. While using chemical coagulant is easier and faster than those methods.

CHAPTER THREE

METHEDOLOGY

3.1. Collected Data from Kasih food Production Company

As mentioned earlier, Kasih food Production Company is selected for this study as it is one of the leading Jordanian manufacturers of canned and boxed Mediterranean food. It does not have wastewater treatment plant so the wastewater is discharged in the sewer system without any treatment. During site visit to Kasih Company a full description about the productions processes and the wastewater resources (effluent 1 and effluent 2) from bean and effluent 3 from dried yoghurt processes provided by the engineer as shown previously in Figures (1.1, 1.2)

3.2. Collection of samples

The wastewater produced from the bean processes (Soaking and Blanching) and dried yoghurt processes (Soaking for desalting) were used to run the experiments of this study.

The wastewater from each source was collected in containers and transported to the pilot scale in the Royal Scientific Society (RSS) laboratory.

3.3. The pilot scale of the treatment.

As shown in Figure (3.1 a & b) the system in this study consists of jar test and Imhoff cones.

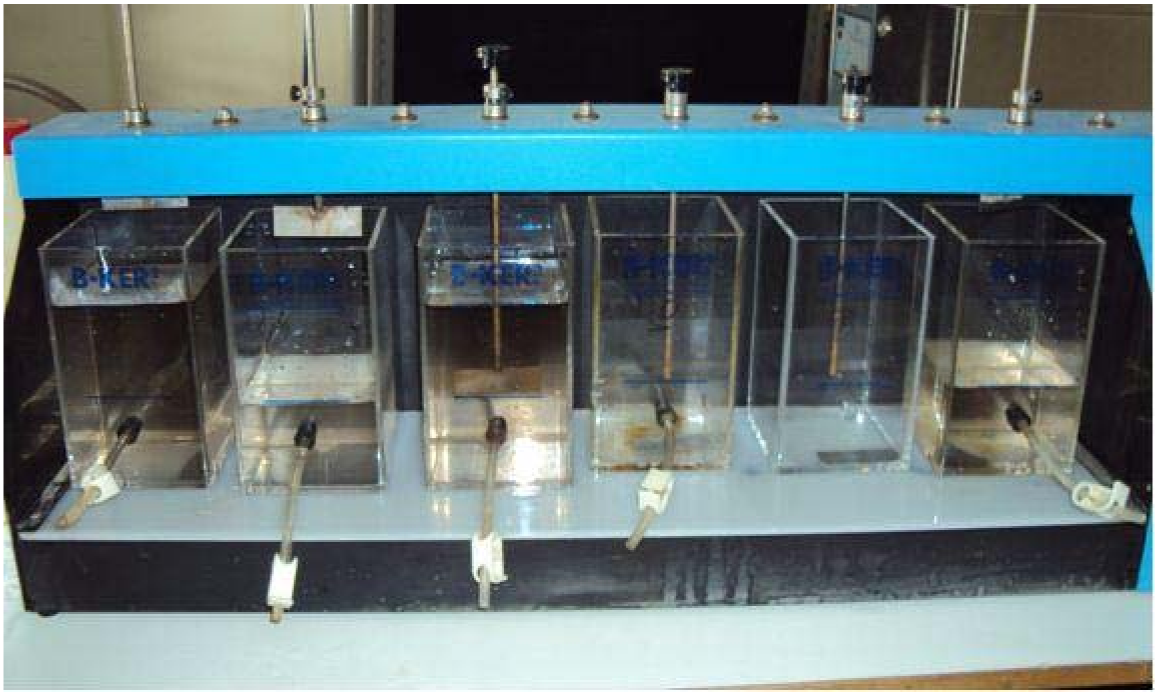

Fig. (3.1 a): Jar Test

Fig. (3.1 b): Imhoff Cones|

Description of system components:

1. An Imhoff cone is simply a cone-shaped plastic container. It holds one liter, with the side of the cone graduated in milliliters.
2. Jar test apparatus with glass beakers and mixers.
3. Portable pocket size pH meter manufactured by WTW, model InoLab pH 720. Its accuracy is ± 0.01 pH
4. Magnetic stirrers manufactured by Metrohm model 728 and magnetic rods.
5. Balance for weighting the required chemical coagulant manufactured by SHIMADZU model AY 220. Its accuracy is ± 0.1 mg
6. Chemical coagulant (ferric chloride) and chitosan polymer. Where ferric chloride coagulant supplied by Nice Chemicals-India and chitosan polymer by SIGMA-Al Drich (C3646-25G)
7. Glass funnels and filters papers 7cm and 0.45 µm pore size.

3.4. Experiments procedures

From literature review it was noticed that many studies were performed using different methods of bean soaking and blanching and liquid yoghurt desalting wastewater treatment. However, few researches about bean and dried yoghurt wastewater treatment by chemical coagulation were found. Therefore, Coagulation-Flocculation is used in this research. The experiments of this study were performed to study the effect of two variables: pH and chemicals dosages on the efficiency of the wastewater treatment. All of the experiments were carried out at a room temperature in the range of the 20-26°C.

3.4.1. Settling by imhoff cone experiment

Settling studies on bean blanching and dried yoghurt desalting wastewater were performed by Imhoff cone which is simply a cone-shaped plastic container. It holds one liter, with the side of the cone graduated in milliliters.

The following steps were followed in the settling steps according to Standard Methods for the Examination of Water and Wastewater, 2540 A, 2540 F (1999):

1. Six imhoff cones are filled to the one-liter mark with a well mixed sample.
2. The sample is allowed to settle in the imhoff cone for 45 minutes.
3. The sample is gently stirred with a glass rod to release the suspended matter clinging to the sides of the imhoff cone.
4. The sample is allowed to settle for an additional 15 minutes.
5. At this point, one hour has passed. The volume of settleable solids in the imhoff cone is recorded in milliliters.

3.4.2. Coagulation-Flocculation experiments

Coagulation studies on samples are performed with jar test equipment (Phipps and Bird Inc. catalog # 7790-902 B) comprising of six paddle rotors (24.5 mm x 63.5 mm), equipped with 6 beakers of two litters each.

The following steps are followed in the coagulant steps:

1. The beakers are filled with samples.
2. A practical dose of the coagulant is added to test the optimal pH (OpH) to get the maximum BOD and COD removal, the OpH is found by varying the initial pH to 4, 5, 6 and 7 by the addition of concentrated hydrochloric acid and/or sodium hydroxide (6 N).
3. The optimal coagulant dose (OpCD) is tested by varying the dose of coagulant- according to the type of wastewater sample- using the OpH found earlier.
4. The initial rapid mixing stage of the experiment is 1 min at 100 rpm, followed by slow mixing stage for 30 min at 30 rpm. The final gravity settling stage lasted for another 30 min.
5. Samples are tested for the determination of BOD, COD, TSS, TDS and alkalinity.
6. The procedure is carried for two type of coagulant: Ferric chloride ($FeCl_3$) for bean soaking and blanching and Chitosan for liquid yoghurt desalting.

The maximum ratio of sBOD/BOD_T and sCOD/COD_T is about 0.6 and 0.47 respectively, for food industrial wastewater (Nakhla et al., 2006). Because the suspended solids are removed by imhoff cones so the total BOD measurement contains high percentage of soluble BOD type.

3.5. Samples analysis

At the beginning of each experiment, before pH adjustment, an initial sample is taken and analyzed to determine the BOD, COD, TSS, TDS, pH and alkalinity. The above mentioned tests were performed at The Water Authority of Jordan (WAJ) laboratories, according to Standard Methods for the Examination of Water and Wastewater issued by American Public Health Association (APHA). Samples analyses were undertaken in Triplicates.

The pH was measured by pH meter WTW ILOLAB (pH 720).

The BOD is determined in accordance with the method 5210 B for measurements of oxygen consumed in a 5-d test period (APHA, 1995). The COD is determined in accordance with the method 5220 B (Closed reflux, Titrimetric method) of the standard methods for the examination of water and wastewater (APHA, 1995), The TDS is tested in accordance with the method 2540 C and The TSS by the method 2540 D (APHA, 1995).

CHAPTER FOUR

Results and Discussion

4.1. Introduction

This chapter is divided into four main parts; the first part discusses the results of the bean soaking and blanching wastewater and dried yoghurt desalting effluents characterization. The second part studies the settling in imhoff cone and the third part discusses the experiments which are conducted to determine the optimum pH (OpH). Finally, the last part focuses on the effect of adding different doses of coagulant on the wastewater and the optimum coagulant dose (OpCD) determination. The studied variables are: the optimum dose and pH effect.

4.2. Wastewater characterization

The wastewater treated in this study was collected from three different sources, one from soaking bean process, the other from blanching bean process as shown in last section in Fig. 3.1 and the third one from dried yoghurt desalting process as shown in previously in Fig. 3.2. Tables 4.1, 4.2 and 4.3 list the readings and averages analysis results performed on the samples.

Table (4.1): Bean soaking wastewater (Effluent 1 as shown in Fig. 3.1) characterization

Parameter	Number of samples	Readings	Average
pH	3	5.0, 5.46, 5.52	5.32
BOD_5 (mg/l)	3	1773, 1996, 2034.5	1934.5
COD (mg/l)	3	1900, 4060, 4420	3460
TDS (mg/l)	3	2893, 3353, 4623	3623
TSS (mg/l)	3	249.5, 367, 432	349.5
Alkalinity (mg/l)	3	343, 479, 561	461

Table (4.2): Bean blanching wastewater (Effluent 2 as shown in Fig. 3.1) characterization

Parameter	Number of samples	Readings	Average
pH	3	4.82, 6.0, 7.12	5.98
BOD_5 (mg/l)	3	2075, 3371, 3779	3075
COD (mg/l)	3	5002, 5093, 6547.5	5547.5
TDS (mg/l)	3	3140, 4247, 5354	3193.5
TSS (mg/l)	3	448, 478, 583	503
Alkalinity (mg/l)	3	83, 89.5, 156	109.5

Table (4.3): Dried yoghurt desalting wastewater (Effluent 3 as shown in Fig. 3.2) characterization

Parameter	Number of samples	Readings	Average
pH	4	4.04, 4.39, 4.41, 4.45	4.32
BOD_5 (mg/l)	4	2243, 2411, 3741, 8896	4322
COD (mg/l)	4	4802, 6322, 9556, 9680	7590
TDS (mg/l)	4	15442, 15610, 22460, 25845	19839
TSS (mg/l)	4	1280, 2050, 3162, 4620	2778
Alkalinity (mg/l)	4	0 - <2.5	0

As resulted from wastewater analysis, BOD/COD is larger than 0.5 so anaerobic treatment is better to use, but because it need expert design and construction so the coagulation-flocculation method is preferred to use.

4.3. Settling in Imhoff cones

Settling studies on bean blanching and dried yoghurt desalting wastewater are performed by Imhoff cone before entering the jar test because suspended solids concentration can reduce by settling.

Obtained data are summarized in Table (4.4). Figures (4.1 a & b) and (4.2 a & b) show the settling suspended solids of bean blanching and dried yoghurt soaking wastewater in imhoff cones.

Table (4.4): Sludge Volume Index (ml/l) of Imhoff cones for bean blanching and dried yoghurt soaking wastewater.

Wastewater Source	**pH_{in}**	**Sludge Volume Index (ml/l)**
Bean blanching	6.67-7.05	0.5-2.5
Dried yoghurt soaking	4.04-4.41	3.5-35

As shown in Table 4.4, the range of sludge volume index (SVI) was low and inefficient for suspended solids removal.

Fig. (4.1 a): Bean blanching wastewater in imhoff cone before settling

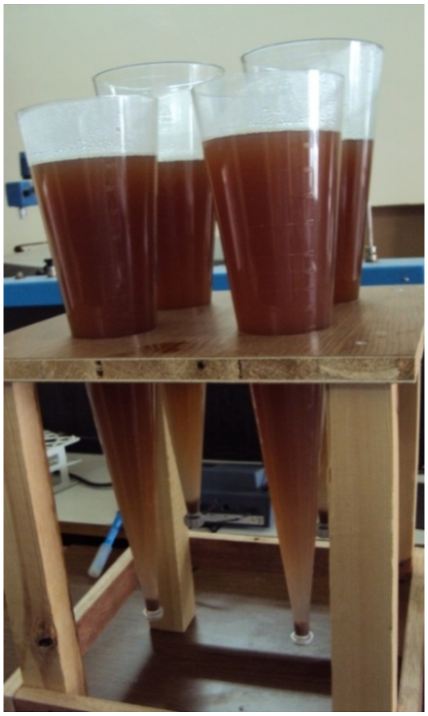

Fig. (4.1 b): Bean blanching wastewater in imhoff cone after settling

Fig. (4.2 a): Dried yoghurt soaking wastewater in imhoff before settling

Fig. (4.2 b): Dried yoghurt soaking wastewater in imhoff cone after settling.

4.4. The optimum pH (OpH) determination for bean soaking and blanching wastewater contaminant removal by ferric chloride coagulant.

The influence of pH in a range of 4-7 on the COD, BOD, TDS and TSS removal is investigated only by the addition of either concentrated hydrochloric acid (HCl) or sodium hydroxide (NaOH) and the practical dose of ferric chloride that is added to the bean soaking wastewater is 150 mg/l $FeCl_3.6H_2O$ while 400 mg/l is added to bean blanching wastewater, to find the optimal pH (OpH) for ferric chloride.

4.4.1 The optimum pH (OpH) for bean soaking and blanching wastewater depending on BOD and COD removal.

Fig. (4.3 a) shows the affect of pH on the removal of BOD and COD of bean soaking wastewater. pH is adjusted by adding of hydrochloric acid or sodium hydroxide and a practical dose of ferric chloride150 mg/l. As it is indicated in the Figure, the maximum BOD and COD removal is 56.58% and 71.6% respectively and it occurred at pH 7.

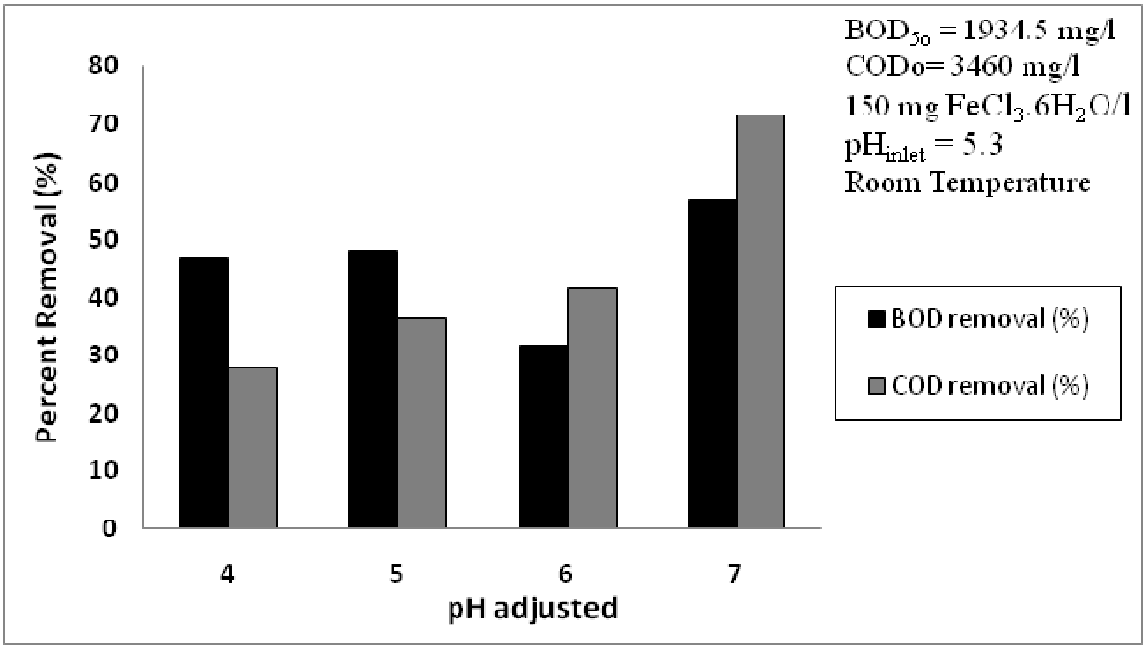

Fig. (4.3 a): Optimum pH (OpH) effect on BOD & COD removal efficiency (%) for bean soaking wastewater by adding practical dose of ferric chloride of 150 mg/l.

Fig. (4.3 b) shows the effect of optimum pH (OpH) values on bean blanching BOD and COD removal in wastewater. The maximum BOD and COD removal was 68.8%, 80.7% respectively, and obtained at pH 7, similar to the case of beans soaking wastewater.

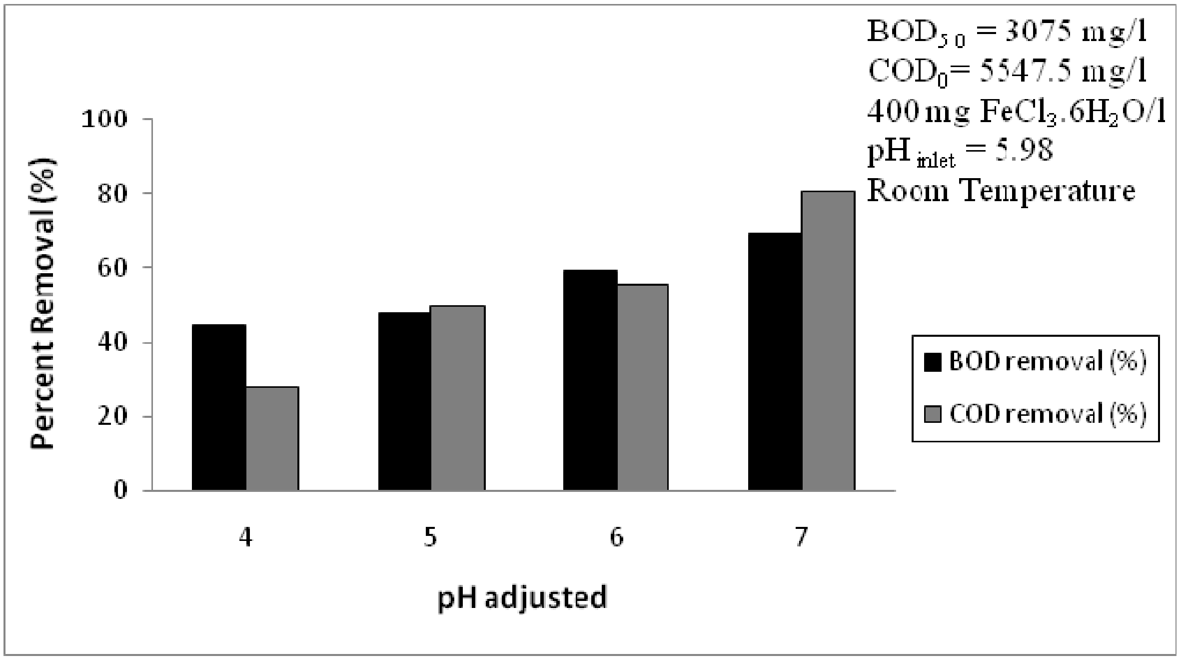

Fig. (4.3 b): Optimum pH (OpH) effect on BOD & COD removal efficiency (%) for bean blanching wastewater by adding 400 mg $FeCl_3.6H_2O$/l.

The result of the effect of pH value on BOD and COD removal for bean soaking and blanching are summarized in Table (4.5) and Table (4.6), respectively.

Table (4.5): The effect of pH value on bean soaking wastewater BOD and COD removal [BOD_{5o}= 1934.5 mg/l, COD_o= 3460 mg/l, at room temperature].

Sample No.	pH Inf.	pH Eff.	BOD Eff. (mg/l)	COD Eff. (mg/l)	BOD removal (%)	COD removal (%)
1	4.0	3.25	1027	2500	46.9	27.75
2	5.0	4.06	1004	2200	48.1	36.42
3	6.0	5.7	1323	2021	31.6	41.59
4	7.0	6.46	840	982	56.58	71.62

Table (4.6): The effect of pH value on bean blanching wastewater BOD and COD removal [BOD_{5o}= 3075 mg/l, COD_o= 5547.5 mg/l, at room temperature].

Sample No.	pH Inf.	pH Eff.	BOD Eff. (mg/l)	COD Eff. (mg/l)	BOD removal (%)	COD removal (%)
1	4.0	2.89	1711	3994	44.36	28
2	5.0	3.25	1604	2800	47.8	49.5
3	6.0	3.91	1257	2456	59.12	55.7
4	7.0	5.61	959	1070	68.8	80.7

4.4.2 Optimum pH (OpH) effect on removal of TSS and TDS for bean soaking and blanching wastewater

Fig. (4.4 a) shows the results of adjusting the pH on bean soaking wastewater by adding hydrochloric acid or sodium hydroxide and adding a practical dose of ferric chloride150 mg/l. The maximum TSS and TDS removal is 37.1% and 38.4%, resulted at pH 7.

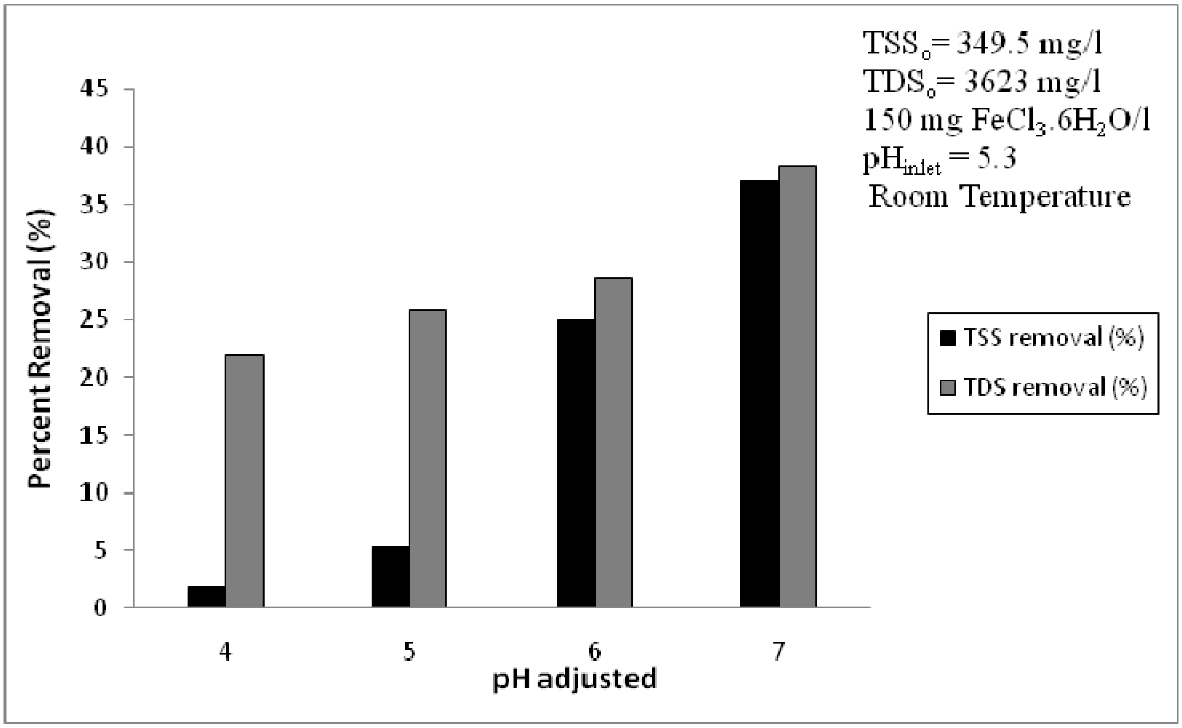

Fig. (4.4 a): Optimum pH (OpH) effect on TSS & TDS removal efficiency (%) for bean soaking wastewater by adding practical dose 150 mg $FeCl_3.6H_2O$/l.

Fig. (4.4 b) shows the effect of changing the pH values on bean blanching wastewater. The maximum TSS and TDS removal was 38.76%, 12% respectively, resulted from adjusting the pH to 7.

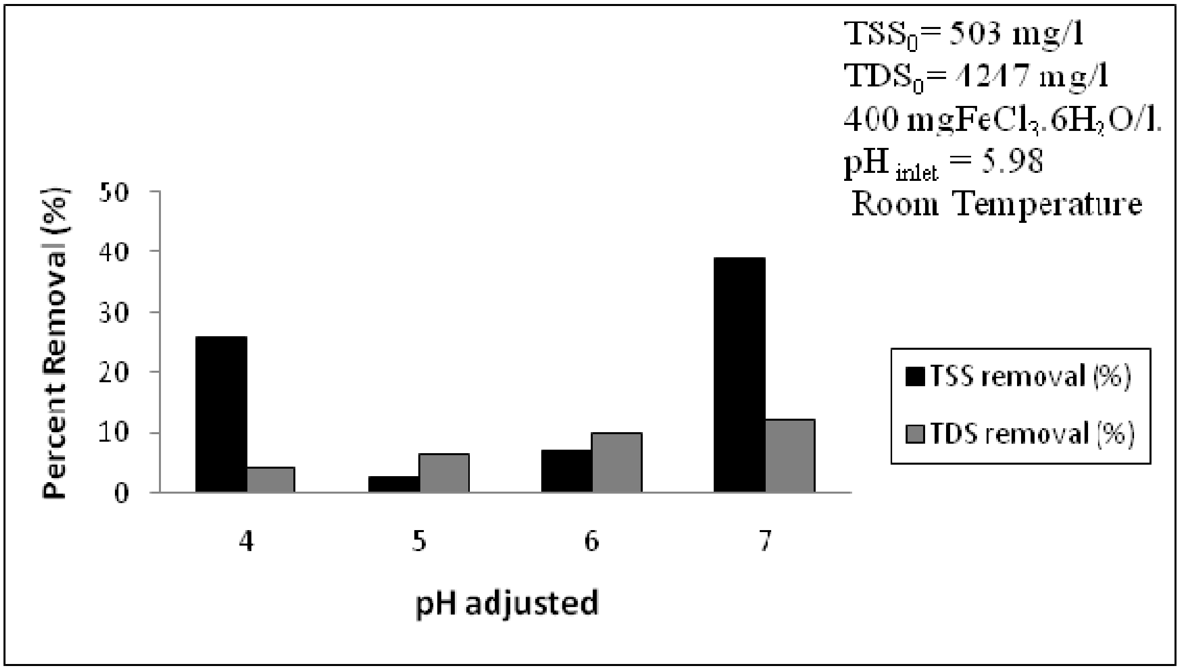

Fig. (4.4 b): Optimum pH (OpH) effect on TSS & TDS removal efficiency (%) for bean blanching wastewater by adding practical dose 400 mg $FeCl_3.6H_2O$/l.

The results of the effect of pH value on TSS and TDS removal for bean soaking and blanching are summarized in Table (4.7) and Table (4.8), respectively.

Table (4.7): The effect of pH value on bean soaking wastewater TSS and TDS removal [TSS_o= 349.5 mg/l, TDS_o= 3623 mg/l, at room temperature].

Sample No.	$pH_{Inf.}$	$pH_{Eff.}$	$TSS_{Eff.}$ (mg/l)	$TDS_{Eff.}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	4.0	3.25	343	2827	1.86	21.97
2	5.0	4.06	331	2687	5.29	25.83
3	6.0	5.7	262	2590	25	28.5
4	7.0	6.46	220	2233	37.05	38.36

Table (4.8): The effect of pH value on bean blanching wastewater TSS and TDS removal [TSS_o= 3075 mg/l, TDS_o= 5547.5 mg/l, at room temperature].

Sample No.	pH $_{Inf.}$	pH $_{Eff.}$	TSS $_{Eff.}$ (mg/l)	TDS $_{Eff.}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	4.0	2.89	373	4073	25.84	4.09
2	5.0	3.25	490	3978	2.6	6.33
3	6.0	3.91	467	3825	7.16	9.9
4	7.0	5.61	308	3737	38.76	12.0

It can be conclude from the previous results that the OpH for both bean soaking and blanching wastewater is 7.0.

SCHNEIDER, et al. treated the wastewater from soybean processing with initial COD 7000-27000mg/l at pH 4.5 by ferric chloride dose 200-300 mg/l and obtained only 28% COD removal, while Badawy et al. get 63% of COD removal at 400 mg/l of ferric chloride with initial mean value of COD 3323 mg/L at the same OpH 7.0 which is more efficient.

4.5. The optimum pH (OpH) determination for dried yoghurt soaking (desalting) wastewater at practical chitosan polymer dose

Experiments were carried out to determine the optimum pH (OpH) depending on BOD, COD, TSS and TDS removal. The practical dose of chitosan polymer which is added for dried yoghurt soaking (desalting) is 45 mg/l.

4.5.1. Optimum pH (OpH) effect on removal of BOD and COD for dried yoghurt soaking (desalting) wastewater.

The effect of pH variation by adding hydrochloric acid or sodium hydroxide and adding a practical dose of chitosan 45 mg/l on BOD and COD reductions are shown in Figure (4.5 a) and Table (4.9). Maximum BOD and COD removals are 76.9% and 60.6% at pH 4, respectively.

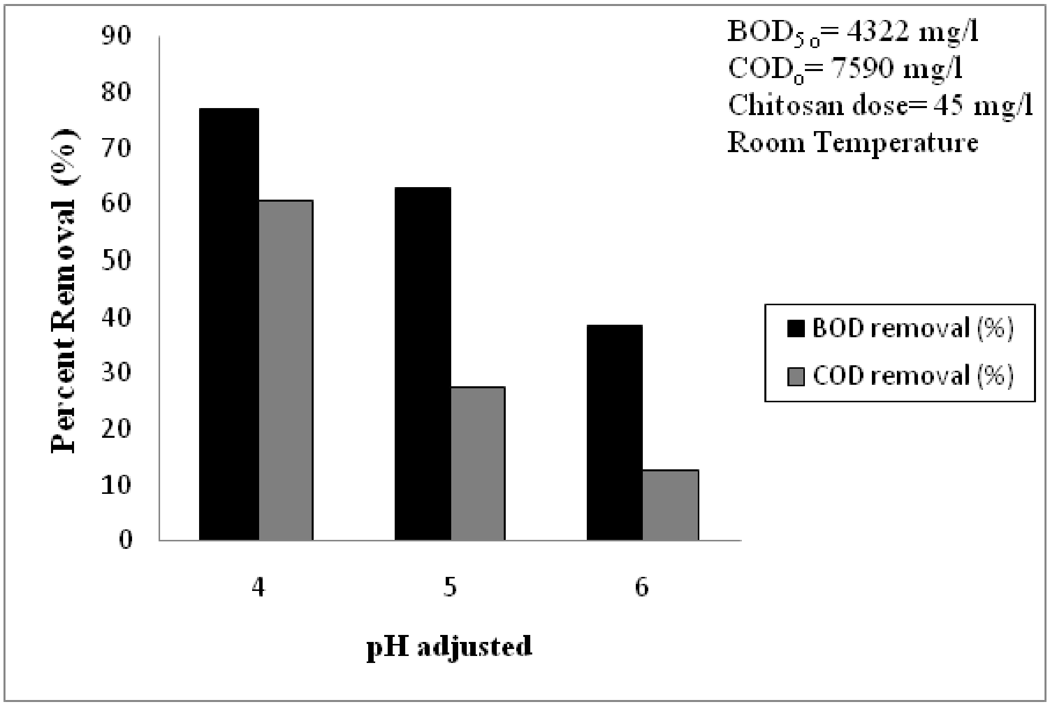

Fig. (4.5 a): Optimum pH (OpH) effect on BOD & COD removal efficiency (%) for dried yoghurt soaking wastewater

Table (4.9): The effect of pH value on bean soaking wastewater BOD and COD removal [$BOD_{5\,o}$= 4322 mg/l, COD_0= 7590 mg/l, chitosan dose= 45 mg/l at room temperature].

Sample No.	Dose, mg/l	pH_{in}	pH_{out}	BOD_{Eff} (mg/l)	COD_{Eff} (mg/l)	BOD removal (%)	COD removal (%)
1	45	4.0	4.18	996	2992	76.9	60.6
2	45	5.0	5.02	1611	5512	62.7	27.4
3	45	6.0	6.1	2659	6631	38.48	12.6

4.5.2. Optimum pH (OpH) effect on removal of TSS and TDS for dried yoghurt soaking (desalting) wastewater.

It can be noticed from Fig. (4.5 b) that OpH is 4.0 for dried yoghurt desalting soaking wastewater. Maximum TSS and TDS removals are 63.8% and 45.1%, respectively. Obtained data are shown in figure (4.5 b) and Table (4.10).

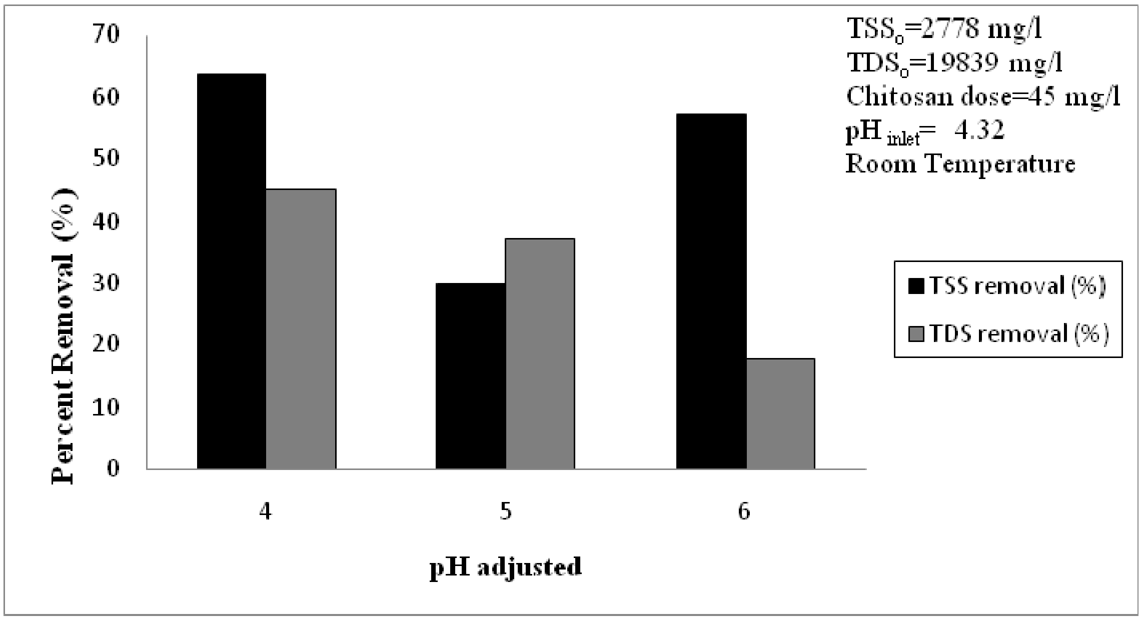

Fig. (4.5 b): Optimum pH (OpH) effect on TSS & TDS removal efficiency (%) for dried yoghurt soaking wastewater with a practical dose of chitosan

Table (4.10): The effect of pH value on bean soaking wastewater TSS and TDS removal [TSS$_o$= 2778 mg/l, TDS$_o$= 19839 mg/l, chitosan dose= 45 mg/l at room temperature].

Sample No.	Dose, mg/l	pH$_{in}$	pH$_{out}$	TSS $_{Eff}$ (mg/l)	TDS $_{Eff}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	45	4.0	4.18	1005	10890	63.82	45.1
2	45	5.0	5.02	1944	12438	30	37.3
3	45	6.0	6.1	1186	16335	57.3	17.7

4.6. Plain Coagulation-Flocculation

Bean soaking and blanching wastewater are treated by the addition of inorganic coagulant Ferric chloride ($FeCl_3.6H_2O$) but the soaking (desalting) wastewater of dried yoghurt are treated by chitosan polymer, in order to examine the effect of the applied physiochemical treatment step on the removal of pollutants. The following sections present the discussion of the results.

Ferric chloride is better than alum because it is well known that uptake of aluminum is associated with Alzheimer's diseases and blood cancer.

Chitosan polymer is chosen to treat dried yoghurt soaking wastewater because it is inexpensive and nontoxic to human, also use of ferric chloride at higher dosages produces orange colored water.

4.6.1. Ferric chloride ($FeCl_3.6H_2O$)

4.6.1.1. The optimum practical coagulant dose (OpCD) of ferric chloride for bean soaking wastewater

The optimum practical coagulant dose (OpCD) of ferric chloride for bean soaking wastewater was tested by varying the ferric dose from 100-300 mg/l ($FeCl_3.6H_2O$) at OpH of 7.0. Fig. (4.6 a) shows the BOD_5 and COD removal obtained due to varying the ferric chloride dose. The highest BOD_5 and COD removal are 91.7%, 89.9%, respectively by using 200 mg $FeCl_3.6H_2O$ /l.

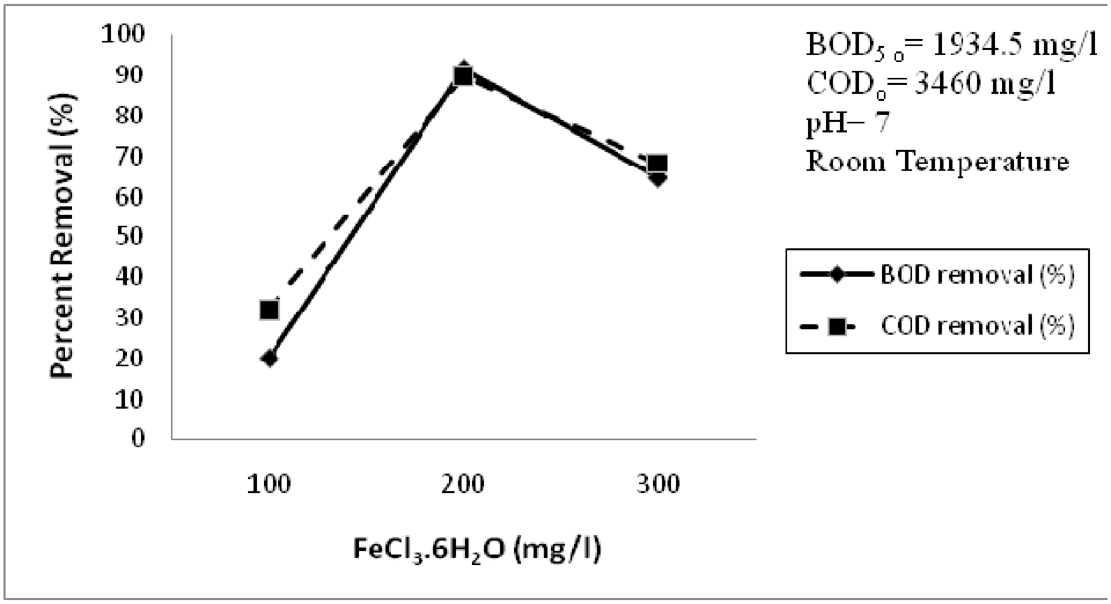

Fig. (4.6 a): BOD_5 and COD removal (%) Vs. $FeCl_3.6H_2O$ (mg/l) for bean soaking wastewater.

Figure (4.6 b) shows that 57.9% TSS removal and 66.1% TDS removal resulting from using 200 mg $FeCl_3.6H_2O$ /l.

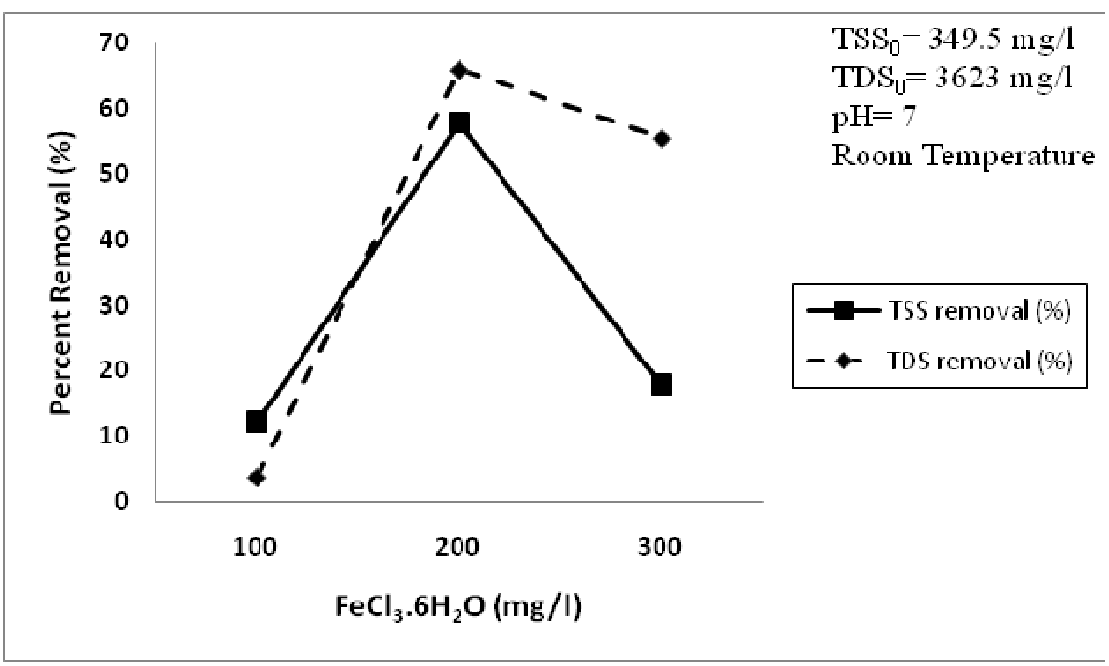

Fig. (4.6 b): TSS and TDS removal (%) Vs. $FeCl_3.6H_2O$ (mg/l) for bean soaking wastewater.

As shown in Figures (4.7 a, 4.7 b, 4.7 c) there is an obvious settling at 200 mg $FeCl_3.6H_2O$ / l and the color of wastewater became clear.

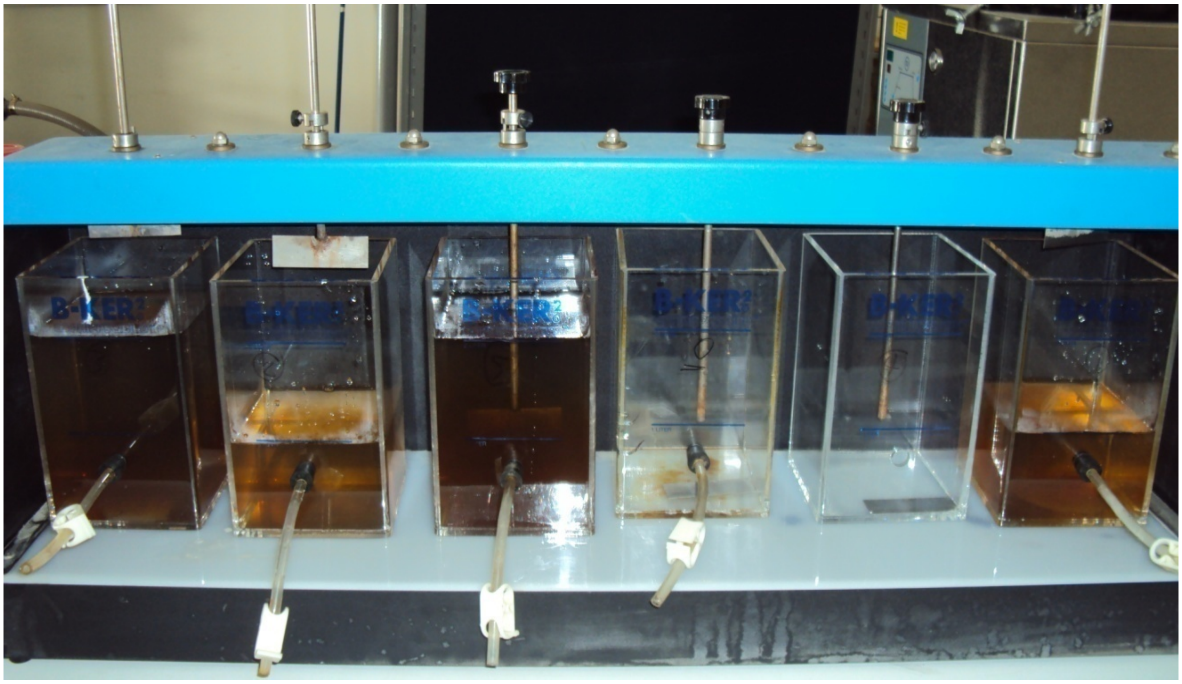

Fig. (4.7 a): Bean soaking wastewater after dosing with ferric chloride

Fig. (4.7 b): Bean soaking wastewater at 200 mg $FeCl_3.6H_2O$ /l after mixing in jar test

Fig. (4.7 c): Bean soaking at 200 mg $FeCl_3.6H_2O$ /l after 30 min settling

4.6.1.2. The optimum practical coagulant dose (OpCD) of ferric chloride for bean blanching wastewater

The OpCD for treating the bean blanching wastewater is found in a similar manner to that of bean soaking wastewater. The ferric chloride range was from 100-600 mg $FeCl_3.6H_2O$ /l. From Fig. (4.8 a) it can be seen that the highest BOD_5 and COD removal (89.9%, 90.8%), respectively occurred when 500 mg $FeCl_3.6H_2O$ /l is added to the sample.

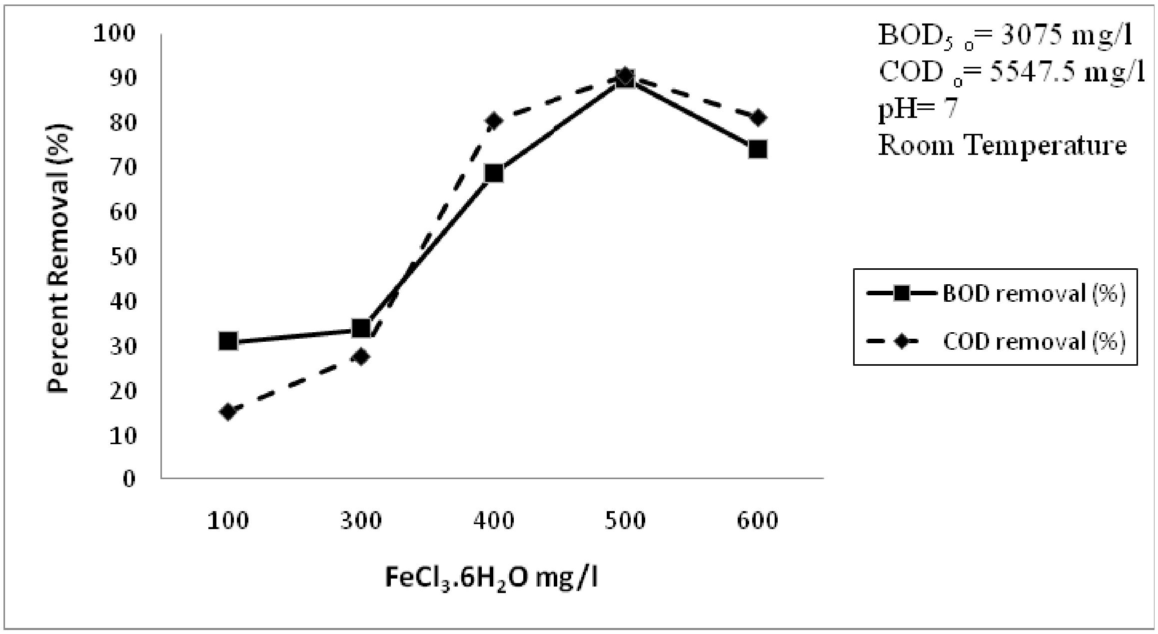

Fig. (4.8 a): BOD_5 and COD removal (%) Vs. $FeCl_3.6H_2O$ (mg /l) for bean blanching wastewater.

Fig. (4.8 b) shows that 75.15% TSS removal occurred at the OpCD, while 61.8% TDS removal was obtained using the same dosage.

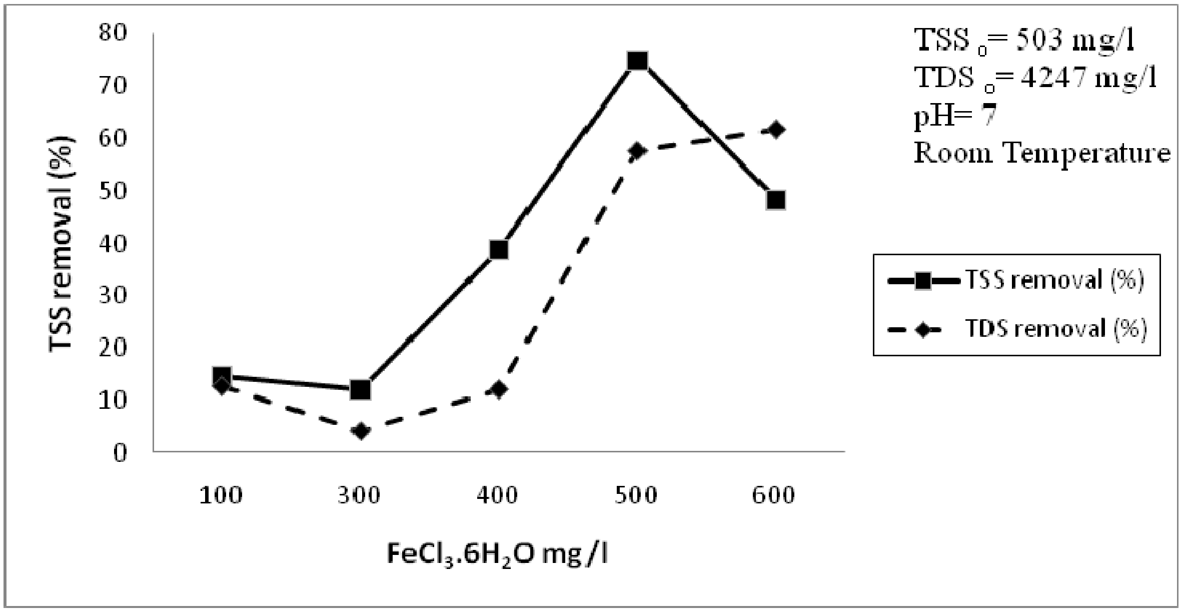

Fig. (4.8 b): TSS and TDS removal (%) Vs. $FeCl_3.6H_2O$ (mg /l) for blanching wastewater.

The results of varying the ferric chloride dose are summarized in Table (4.11) and Table (4.12) for bean soaking wastewater and Table (4.13), Table (4.14) for blanching wastewater.

Table (4.11): The effect of OpCD value of bean soaking wastewater on BOD and COD removal [BOD_{5o}= 1934.5 mg/l, COD_o= 3460 mg/l, pH= 7.0 at room temperature].

Sample No.	Ferric chloride dose (mg/l)	$pH_{Eff.}$	$BOD_{Eff.}$ (mg/l)	$COD_{Eff.}$ (mg/l)	BOD removal (%)	COD removal (%)
1	100	6.9	1550	2360	19.9	31.8
2	200	6.67	160	349	91.7	89.9
3	300	5.64	683	1100	64.7	68.2

Table (4.12): The effect of OpCD value of bean soaking wastewater on TSS and TDS removal [TSS_o= 349.5 mg/l, TDS_o= 3623 mg/l, pH= 7.0 at room temperature].

Sample No.	Ferric chloride dose (mg/l)	$pH_{Eff.}$	$TSS_{Eff.}$ (mg/l)	$TDS_{Eff.}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	100	6.9	307	3487	12.16	3.75
2	200	6.67	147	1230	57.94	66.05
3	300	5.64	287	1610	17.88	55.56

Table (4.13): The effect of OpCD value of bean blanching wastewater on BOD and COD removal [BOD_{5o}= 3075 mg/l, COD_o= 5547.5 mg/l, pH= 7.0 at room temperature].

Sample No.	Ferric chloride dose (mg/l)	$pH_{Eff.}$	$BOD_{Eff.}$ (mg/l)	$COD_{Eff.}$ (mg/l)	BOD removal (%)	COD removal (%)
1	100	6.98	2119	4684	31.09	15.56
2	300	6.21	2029	3998	34.01	27.93
3	400	5.61	959	1070	68.8	80.7
4	500	3.83	310	508	89.9	90.84
5	600	4.01	793	1030	74.21	81.4

Table (4.14): The effect of OpCD value of bean blanching wastewater on TSS and TDS removal [TSS_o= 503 mg/l, TDS_o= 4247 mg/l, pH= 7.0 at room temperature].

Sample No.	Ferric chloride dose (mg/l)	$pH_{Eff.}$	$TSS_{Eff.}$ (mg/l)	$TDS_{Eff.}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	100	6.98	430	3713	14.5	12.57
2	300	6.21	443	4077	11.9	4.0
3	400	5.61	308	3737	38.76	12.0
4	500	3.83	125	1800	75.15	57.62
5	600	4.01	260	1622	48.3	61.80

As shown from results, by using OpCD 200 mg $FeCl_3.6H_2O$/l for bean soaking wastewater and 500 mg $FeCl_3.6H_2O$/l for bean blanching wastewater treatment the required BOD,

COD, TSS and TDS concentration is achieved according to Jordanian standard (JS 202:2007) of industrial reclaimed wastewater for field crop and forest trees irrigation.

The color of blanching wastewater changed from dark brown to clear pale yellow using ferric chloride as shown in Figures (4.9 a, 4.9 b, 4.9 c).

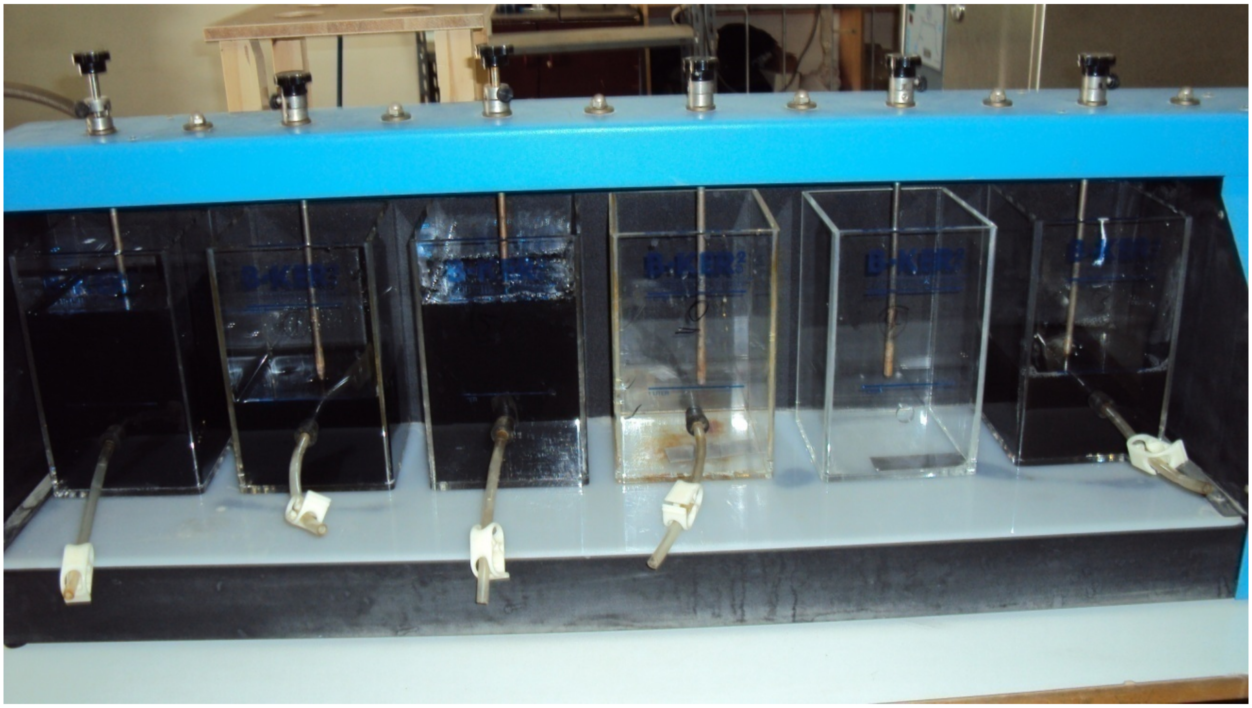

Fig.(4.9 a): Bean blanching wastewater after dosing with ferric chloride.

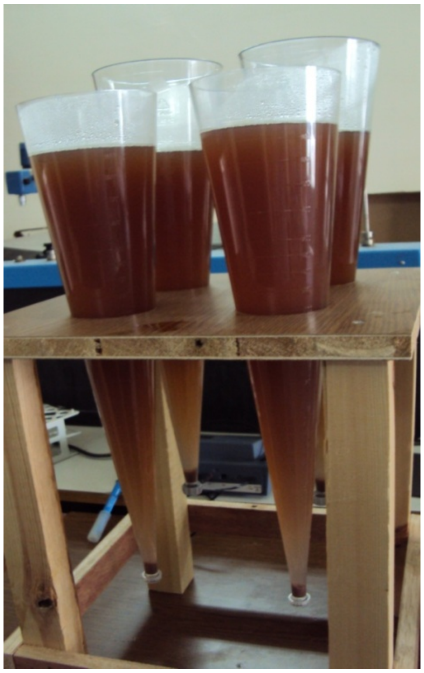

Fig. (4.9 b): Blanching wastewater before the treatment.

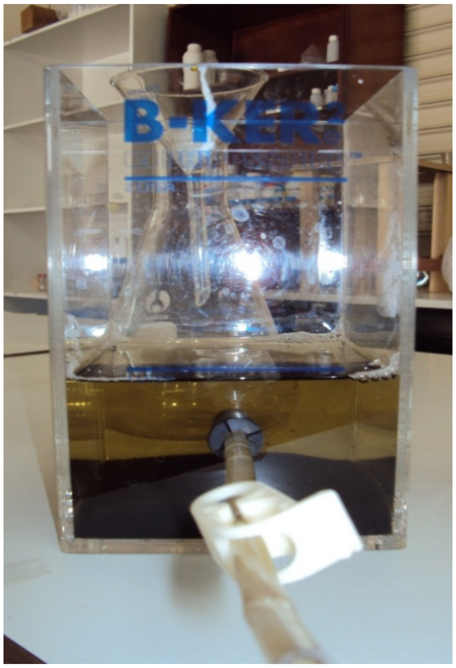

Fig. (4.9 c): Blanching wastewater after the treatment.

4.6.2. Chitosan polymer as a coagulant

4.6.2.1. The optimum practical coagulant dose (OpCD) of dried yoghurt soaking (desalting) wastewater

After establishing the OpH as mentioned in last section, the OpCD are tested by varying the chitosan polymer between 10 mg/l and 80 mg/l. the obtained data are shown in Table (4.15) and Fig.(4.10 a), which show that the OpCD for chitosan polymer is 30 mg/l with maximum 84% BOD removal and 74.3 % COD removal at pH 4.

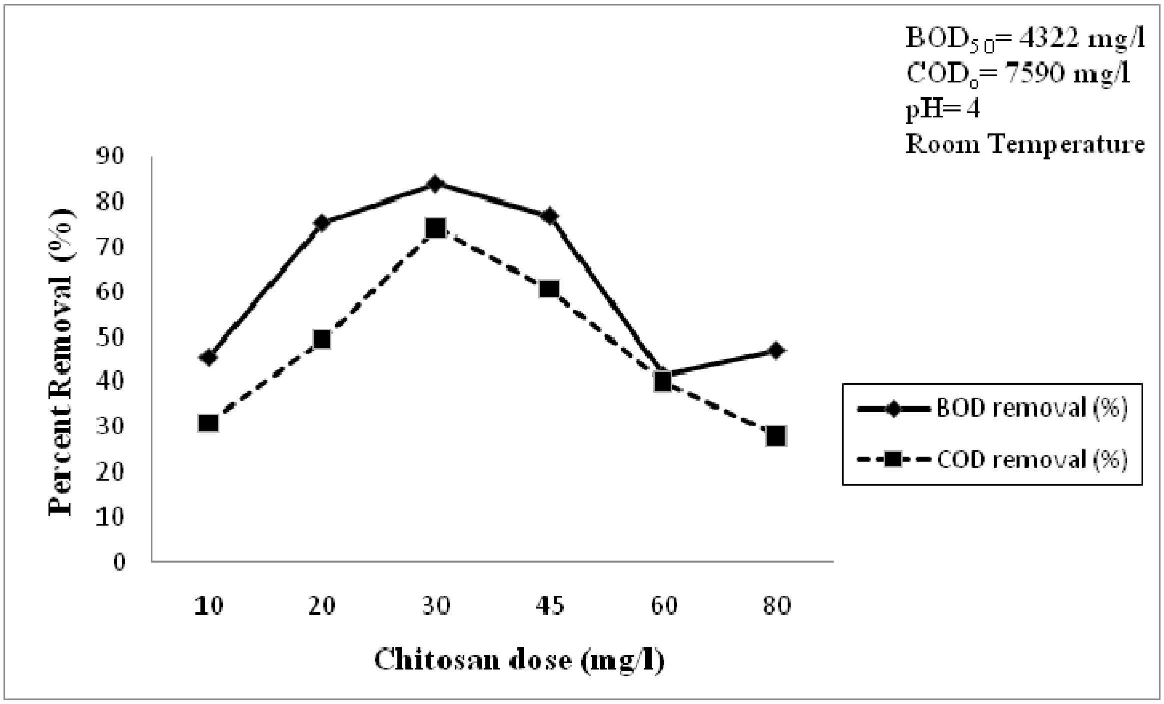

Fig. (4.10 a): BOD_5 and COD removal (%) Vs. Chitosan polymer doses for dried yoghurt soaking wastewater

Table (4.15): The OpCD value of dried yoghurt soaking (desalting) wastewater on BOD and COD removal [BOD_{50}=4322 mg/l, COD_o= 7590 mg/l and pH 4 at room temperature]

Sample No.	**Chitosan polymer dose (mg/l)**	**pH $_{Eff}$**	**BOD $_{Eff.}$ (mg/l)**	**COD $_{Eff.}$ (mg/l)**	**BOD removal (%)**	**COD removal (%)**
1	10	4.24	2361	5254	45.37	30.78
2	20	4.49	1067	3842	75.3	49.38
3	30	4.82	691	1954	84	74.3
4	45	4.85	996	2992	76.9	60.6
5	60	4.05	2536	4560	41.3	40
6	80	4.24	2291	5473	47	27.9

The maximum TSS and TDS removal at pH 4 with OpCD of 30 mg/l were 87.3 % and 47 % ,respectively as shown in Table (4.16) and Fig.(4.10 b).

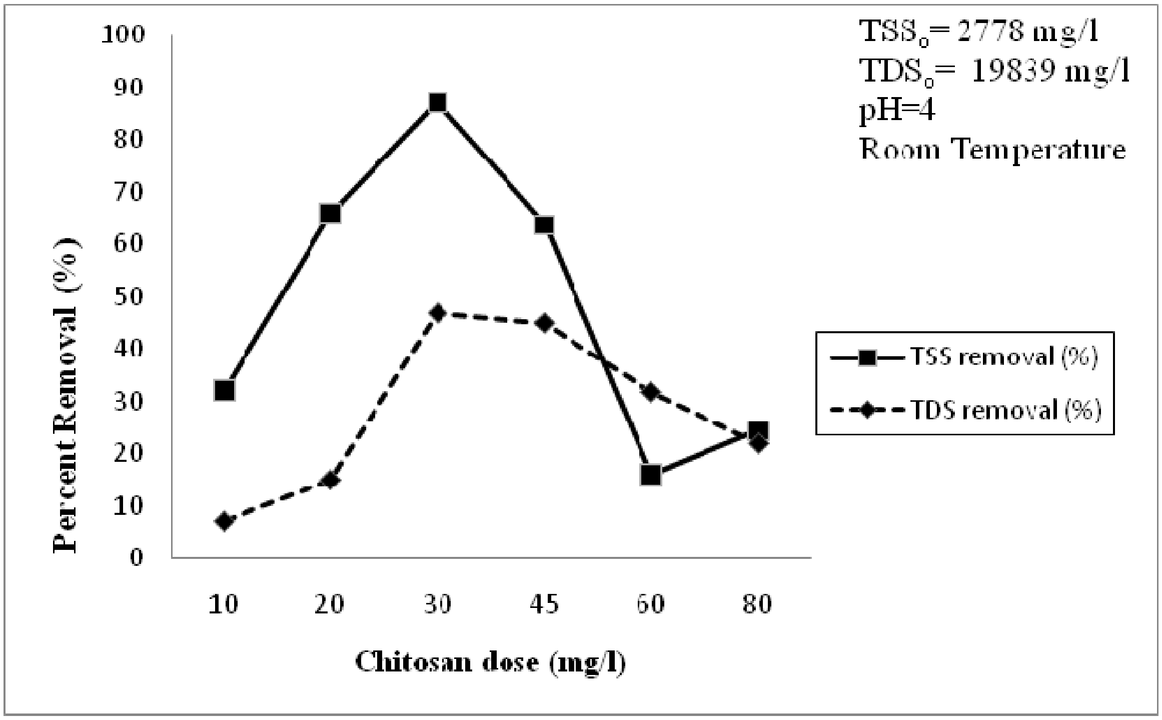

Fig.(4.10 b): TSS and TDS removal (%) Vs. Chitosan polymer for dried yoghurt soaking wastewater

Table (4.16): The OpCD value of dried yoghurt soaking (desalting) wastewater on TSS and TDS removal [TSS_o=2778 mg/l, TDS_o= 19839 mg/l and pH= 4 at room temperature]

Sample No.	Chitosan polymer dose (mg/l)	pH_{Eff}	$TSS_{Eff.}$ (mg/l)	$TDS_{Eff.}$ (mg/l)	TSS removal (%)	TDS removal (%)
1	10	4.24	1883	18400	32.2	7.25
2	20	4.49	943	16830	66.05	15.16
3	30	4.82	352	10520	87.3	47
4	45	4.85	1005	10890	63.82	45.1
5	60	4.05	2333	13500	16	31.95
6	80	4.24	2100	15454	24.4	22.1

Sarkar, et al. (2006) used chitosan polymer as a coagulant to treat dairy industries wastewater at the same OpH (4) but with chitosan polymer dose 10 mg/l, the results of these tests showed that 57% reduction in TDS and 62% COD removal with initial TDS 800-1200 mg/l and COD 1500-3000 mg/l but these results differ from TDS and COD removals obtained for treating dried yoghurt soaking wastewater at the same dose, the COD and TDS is 30.78%, 7.25% respectively, while at pH 6.5 the minimum reduction were occurred with 22% TDS and 20% COD reductions but here the minimum reduction is occurred at pH 5 with 37.3% TDS and 27.4% COD reductions.

Although these results are efficient for BOD, COD, TSS and TDS removal but they do not achieve the Jordanian standard (JS 202:2007) of industrial reclaimed wastewater for field crop and forest trees irrigation.

CHAPTER FIVE

Conclusions and Recommendations

1. Conclusions:

The treatment of the industrial wastewater of Kasih food factory (bean soaking and blanching and dried yoghurt soaking (desalting)) is conducted by coagulation-flocculation; the coagulants are: ferric chloride (for bean soaking and blanching) and chitosan polymer for dried yoghurt soaking. The treatment efficiency is determined by monitoring the initial and the final values of BOD_5, COD, TSS and TDS.

The main conclusions of the research are:

a. Ferric chloride is an efficient coagulant for treating bean soaking and blanching wastewater because it achieved the Jordanian standard for discharging reclaimed wastewater for field crop and forest trees irrigation.

b. pH adjusting of bean soaking wastewater to pH 7 (OpH) and with the addition of practical dose of ferric chloride 150 mg $FeCl_3.6H_2O$/l resulted in 56.58% BOD_5 removal, 71.62% COD removal, 37.05% TSS removal and 38.36% TDS removal, while adjusting the pH of bean blanching wastewater to the same pH resulted in 68.8% BOD_5 reduction, 80.7% COD reduction, %38.76 TSS reduction and 12% TDS reduction.

c. Using pH 4 as optimal pH for dried yoghurt soaking wastewater is more efficient to remove 76.9% BOD_5, 60.6% COD, 63.8% TSS and 45.1% TDS.

d. Coagulation using the (OpCD) 200 mg $FeCl_3.6H_2O$ /l for treating bean soaking wastewater resulted in 91.7% BOD_5 reduction, 89.9% COD reduction, 57.94% TSS reduction and 66.05% TDS reduction, while 500 mg $FeCl_3.6H_2O$/l is used for treating bean blanching wastewater resulted in 89.9% BOD5 reduction, 90.84% COD reduction, %75.15 TSS reduction and 57.62% TDS reduction.

e. Chitosan used as a coagulant for treating dried yoghurt soaking wastewater. The OpCD was 30 mg/l to remove 84 % BOD, 74.3 % COD, 87.3 % TSS and 47 % TDS.

2. Recommendations:

It is recommended to:

a. Study the effect of using alum sulphate for removal BOD, COD, TSS and TDS.

b. Using filtration instead of imhoff cone before entering the wastewater in jar test.

c. Study the effect of mixing speed and settling time on BOD_5, COD, TSS and TDS removal.

d. Measure the soluble BOD to compare it with total BOD and show the removal type of BOD.

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معالجة المياه المستعملة الصناعية في مصنع الكسيح بطريقة التخثر-التلبد والترسيب

اعداد

آلاء بسام الفلايله

المشرف

الدكتور بشار محمد الصمادي

ملخص

المياه الناتجة من الصناعات الغذائية تمثل واحدة من المشاكل البيئية.

تتناول هذه الدراسة معالجة المياه الصناعية الغذائية الناتجة من عملية سلق ونقع الفول وعملية نقع الجميد في مصنع الكسيح للمواد الغذائية. يواجه مشكلة تصريف المياه الناتجة من الصناعات الغذائية الى الصرف الصحي من دون معالجة، والهدف الرئيسي من هذا العمل هو لدراسة معالجة المياه المستعملة الصناعية في مصنع الكسيح لتلبية المعايير الاردنية لتصريف المياه المعالجة لري الاشجار الحرجية والمحاصيل الحقلية بإستخدام التخثر-التلبد والترسيب.

الرقم الهيدروجيني الامثل لمعالجة المياه الناتجة من نقع وسلق الفول هو الرقم 7 وذلك لإزالة 56.58% من الاكسجين المتطلب حيوكيميائيا، 71.62% الاكسجين المتطلب كيميائيا، 37.05% المواد الصلبة العالقة الكلية و 38.36% المواد الصلبة الذائبة الكلية من المياه الناتجة من عملية نقع الفول ، و 68.8% من الاكسجين المتطلب حيوكيميائيا، 80.7% من الاكسجين المتطلب كيميائيا، 38.76% من المواد الصلبة العالقة الكلية و 12% من المواد الصلبة الذائبة الكلية.

لكن الرقم الهيدروجيني الامثل لمعالجة المياه الناتجة من عملية نقع الجميد هو 4، لإزالة 76.9% من الاكسجين المتطلب حيوكيميائيا، 60.6% من الاكسجين المتطلب كيميائيا، 63.8% من المواد الصلبة العالقة الكلية و 45.1% من المواد الصلبة الذائبة الكلية.

كلوريد الحديد أستخدم كمخثر لمعالجة المياه الناتجة من عملية نقع و سلق الفول. النتائج أظهرت ان جرعة المخثر المثلى لمعالجة مياه نقع الفول هي 200 ملغم كلوريد حديد/لتر لإزالة 91.7% من الاكسجين المتطلب حيوكيميائيا، 89.9% من الاكسجين المتطلب كيميائيا،57.94% من المواد الصلبة العالقة الكلية و 66.05% من المواد الصلبة الذائبة الكلية. بينما 500 ملغم كلوريد حديد/ لتر تستخدم لمعالجة المياه الناتجة من سلق الفول واظهرت النتائج انها عملت على ازالة 89.9%

من الاكسجين المتطلب حيوكيميائيا، 90.84% من الاكسجين المتطلب كيميائيا،75.15% من المواد الصلبة العالقة الكلية و 57.62% من المواد الصلبة الذائبة الكلية.

بوليمر (chitosan) أستخدم كمخثر لمعالجة المياه العادمة الناتجة من عملية نقع الجميد. الجرعة المثلى من بوليمر (chitosan) كانت 30 ملغم / لتر لإزالة 84% من الاكسجين المتطلب حيوكيميائيا، 74.3% من الاكسجين المتطلب كيميائيا،87.3% من المواد الصلبة العالقة الكلية و 47% من المواد الصلبة الذائبة الكلية.